Composition, Condition, and Function of Global Land Vegetation

Compton Tucker, John Townshend, Chris Justice, Matt Hansen, Steve Running, Ranga Myneni, Rama Nemani et al.

With special thanks to

Francis Bretherton, Shelby Tilford, and Dixon Butler who got all this started

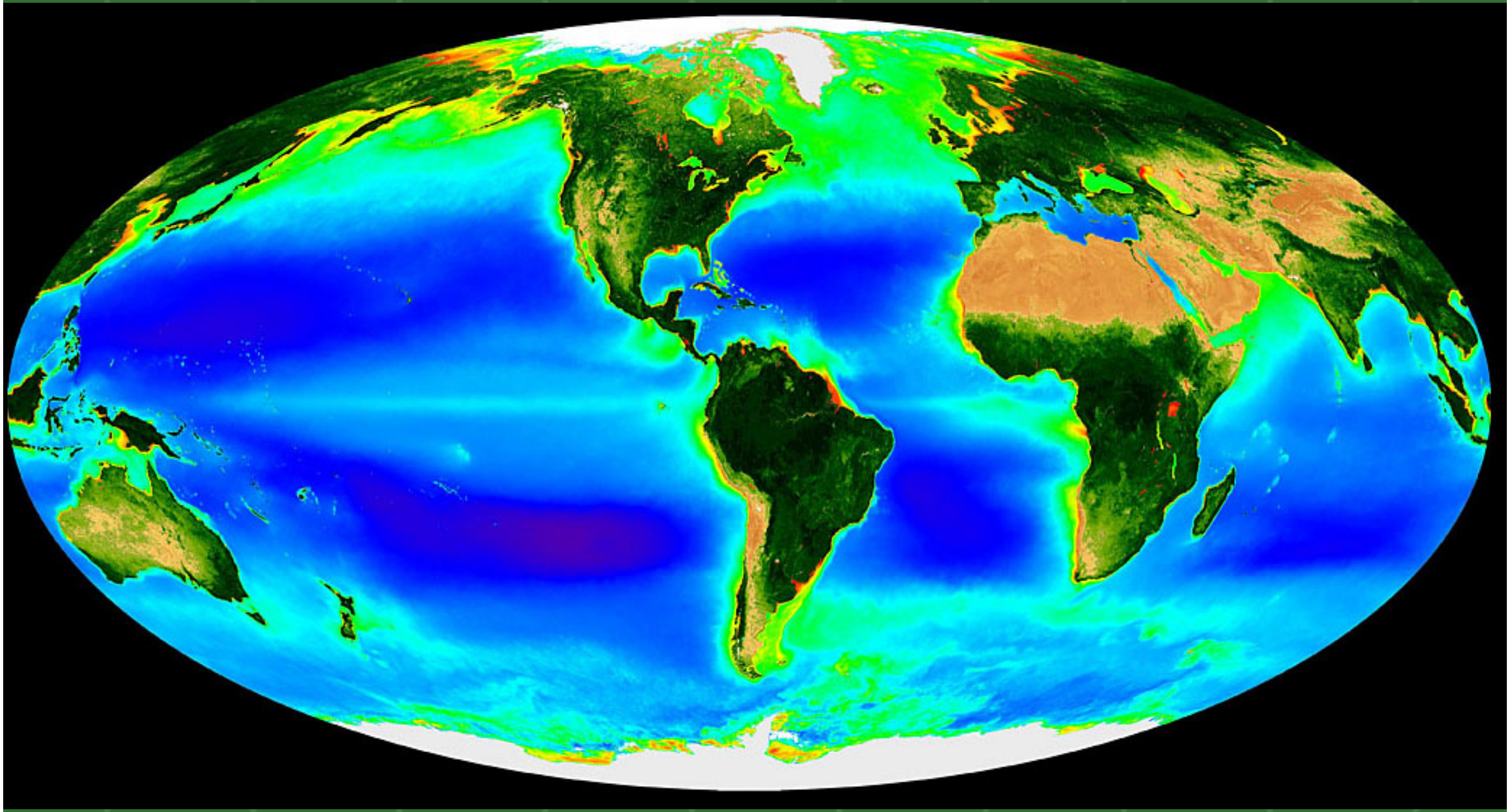
Outline

- Where we were 25 years ago
- Where we are now
- The uncertain road ahead …

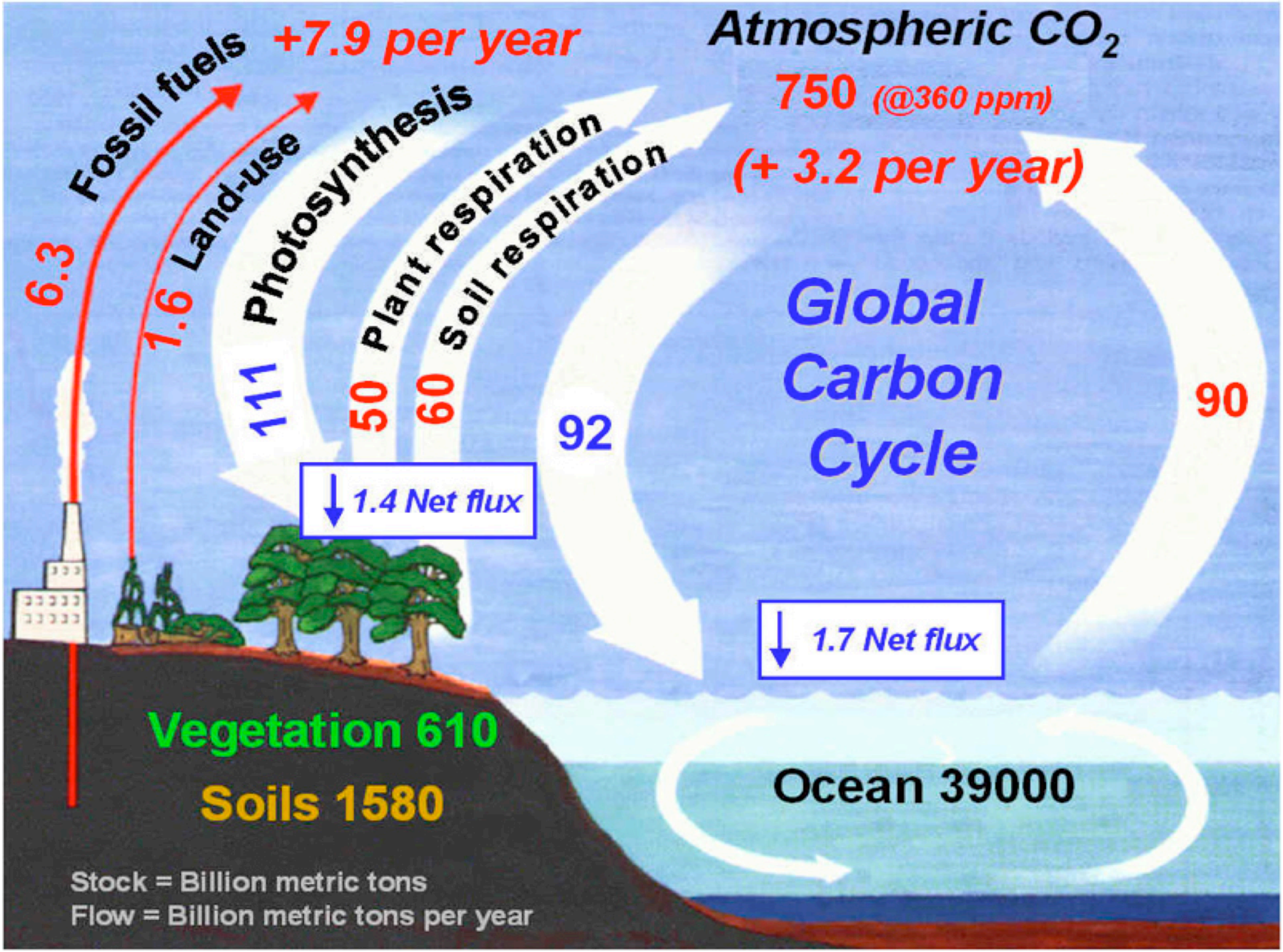
- First, what are we measuring and why is it important?

Our unique planet

The Global Biosphere as revealed by satellites



Earth's a very special place – it's retained liquid H_2O for billions of yrs

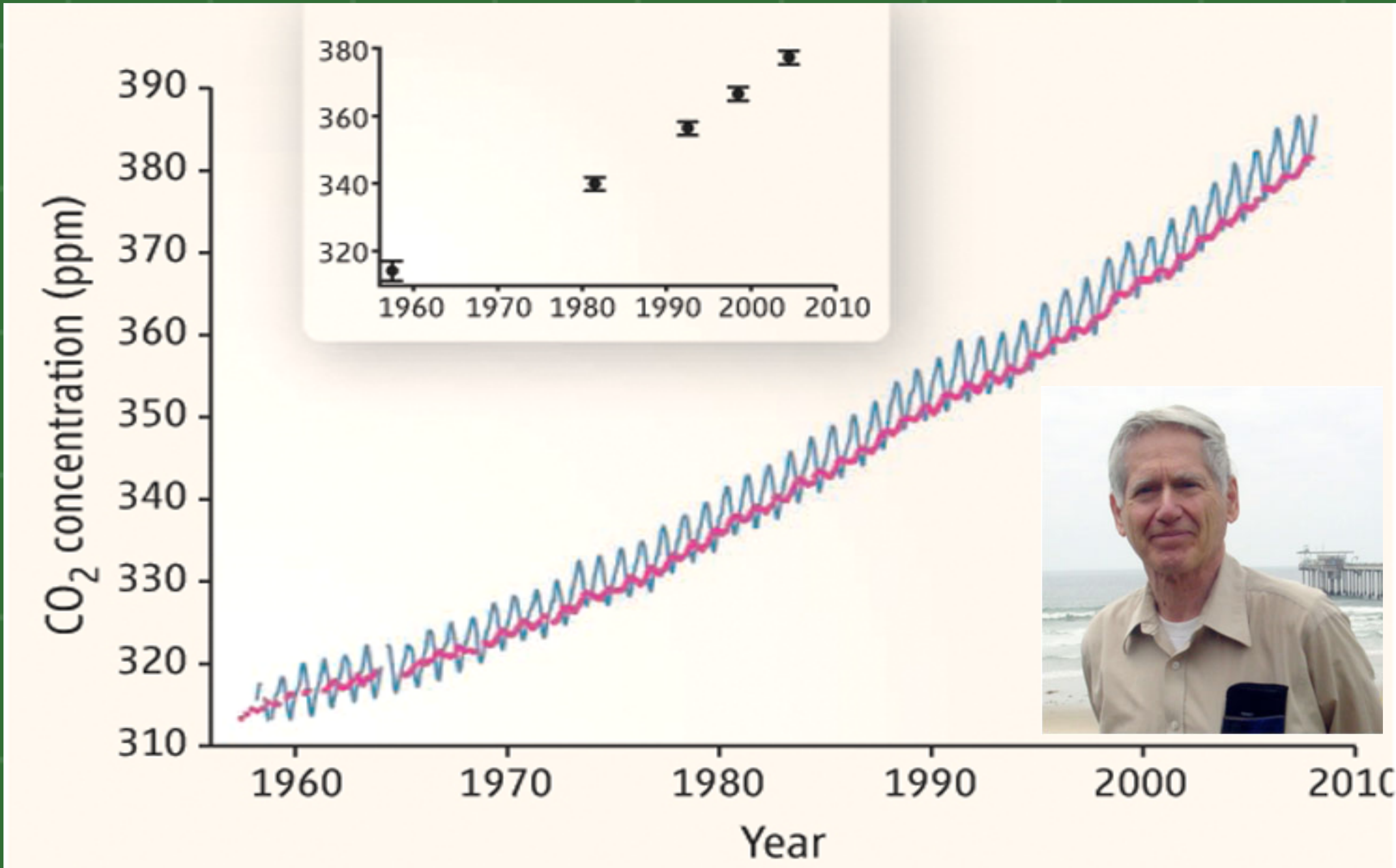

Atmospheric CO_2
750 (@360 ppm)
(+ 3.2 per year)
+7.9 per year
Fossil fuels
6.3
Land-use
1.6
Photosynthesis
111
Plant respiration
50
Soil respiration
60
92
90
Global Carbon Cycle
1.4 Net flux
1.7 Net flux
Vegetation 610
Soils 1580
Ocean 39000
Stock = Billion metric tons
Flow = Billion metric tons per year

Important land carbon fluxes and pools

Fluxes: CO_2 into land vegetation via photosynthesis; CO_2 emitted to the atmosphere from land cover change esp. deforestation; CO_2 emitted to the atmosphere from biomass burning, esp. of forests; Land vegetation respiration

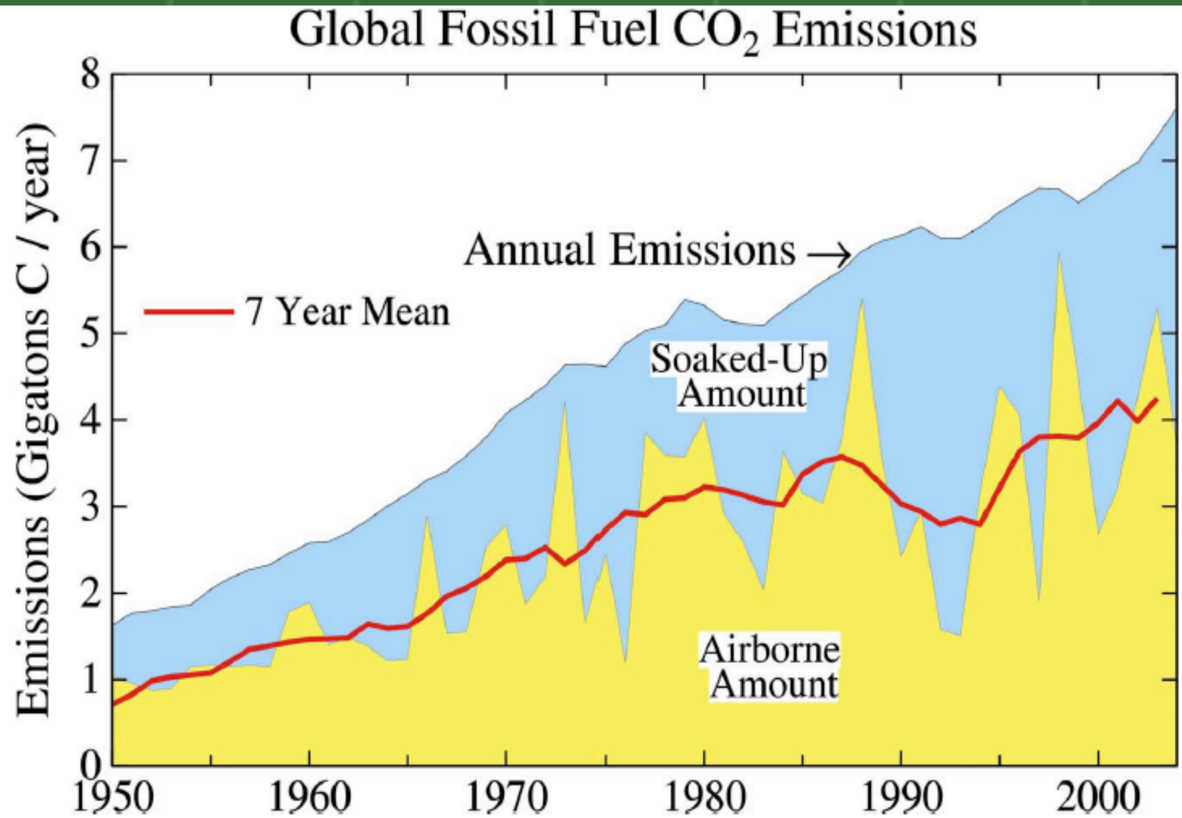
Pools: Carbon stored in land vegetation and soils, including permafrost and peat

Why must we monitor fluxes and pools continually?



Outstanding questions of global carbon cycle

- Where are the ***sinks*** that are absorbing almost 50% of the CO_2 that we emit?
  - Land or ocean?
  - Eurasia/North America?
- Why does CO_2 buildup vary dramatically with nearly uniform emissions?
- How will CO_2 sinks respond to climate change?

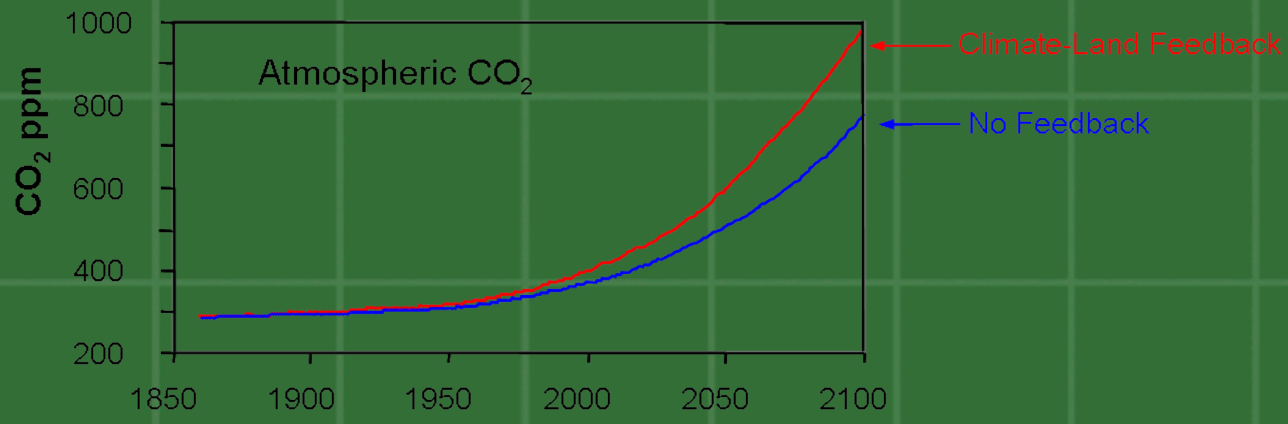


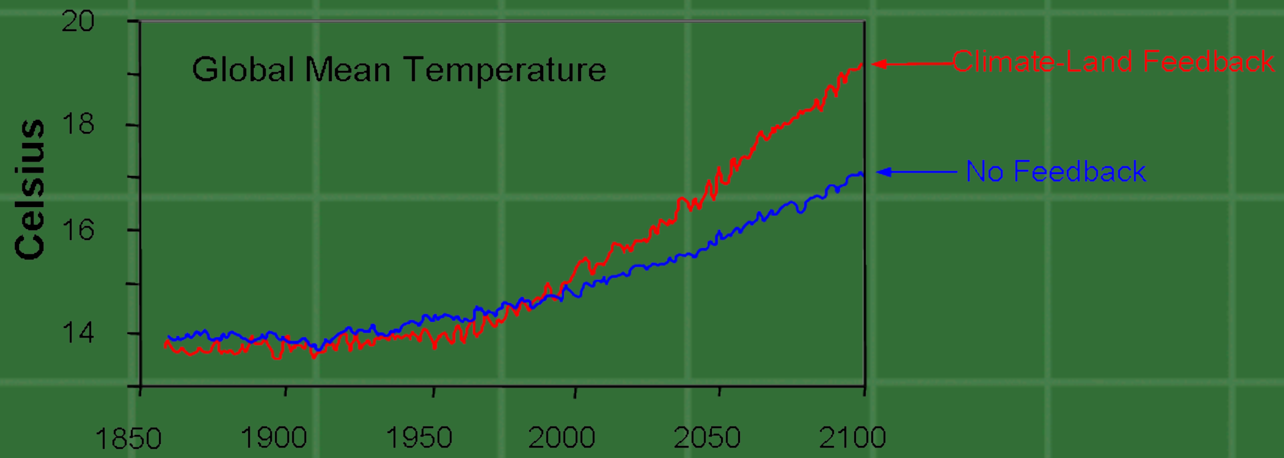
Global fossil fuel CO_2 emissions with division into portions that remain airborne or are soaked up by the ocean and land.

Source: Hansen and Sato, *PNAS*, **101**, 16109, 2004.

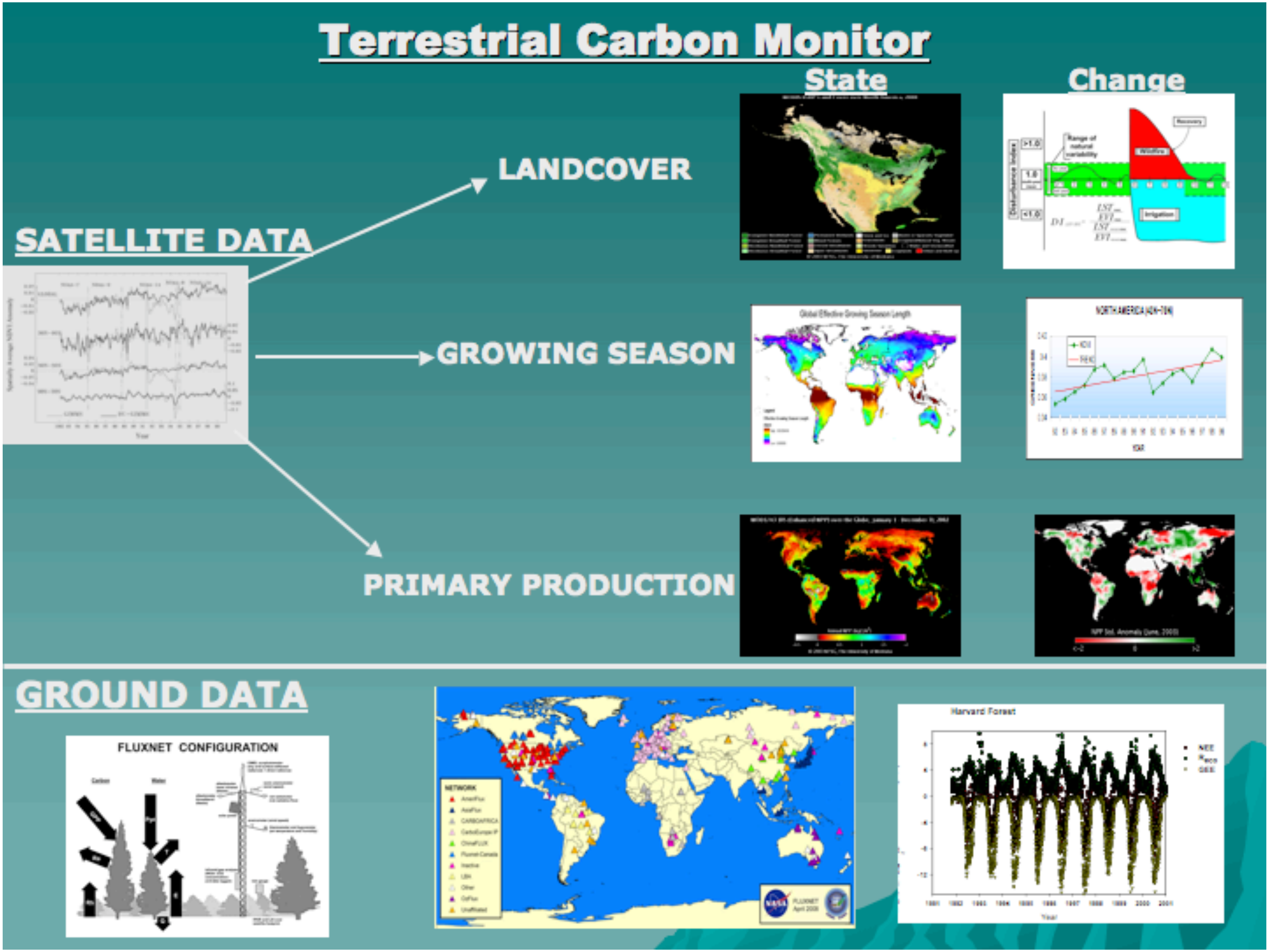
Climate change & Terrestrial carbon cycle

Estimated future CO_2 and temperature for a model, with and without feedbacks between climate change and trees, for the same (standard) fossil fuel emission



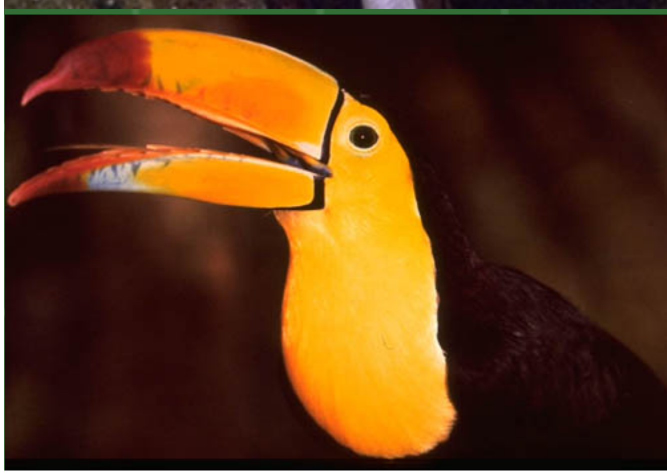


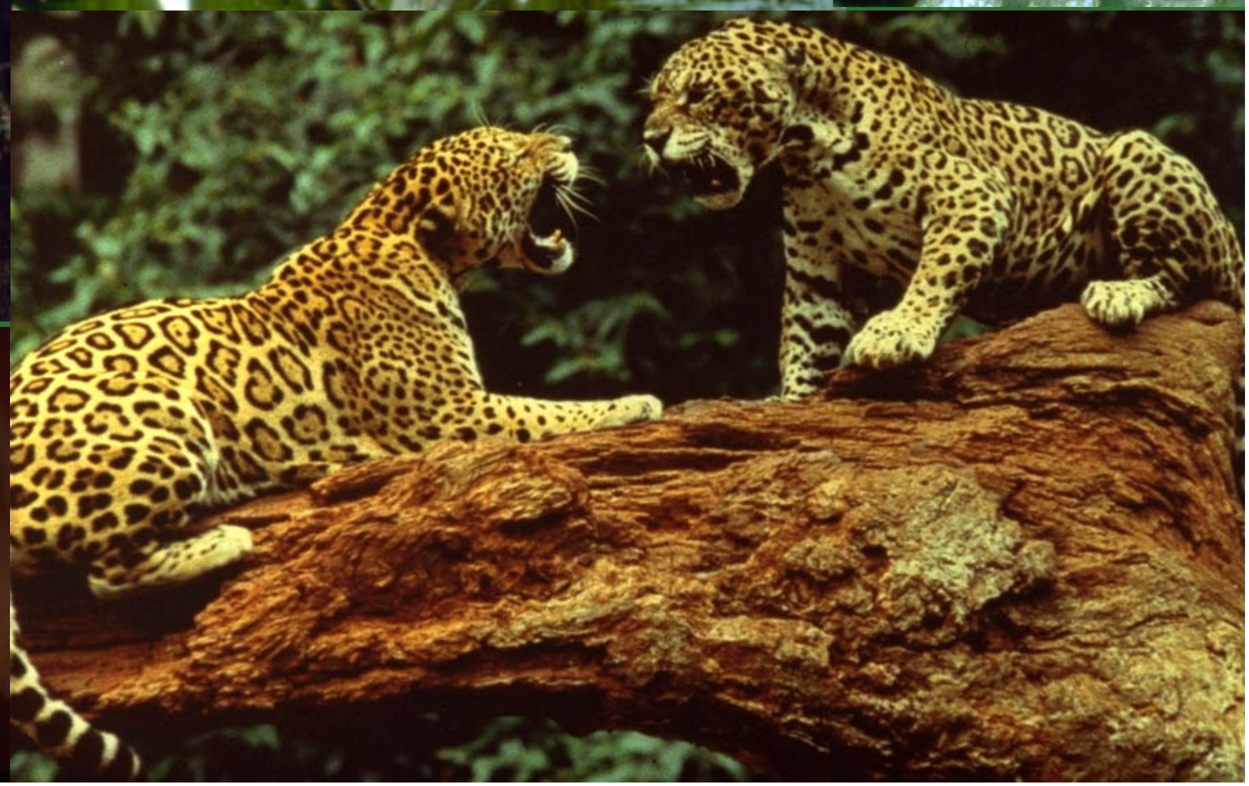
Cox et al., *Nature*, 2000



Running, Nemani, Townshend and Baldocchi

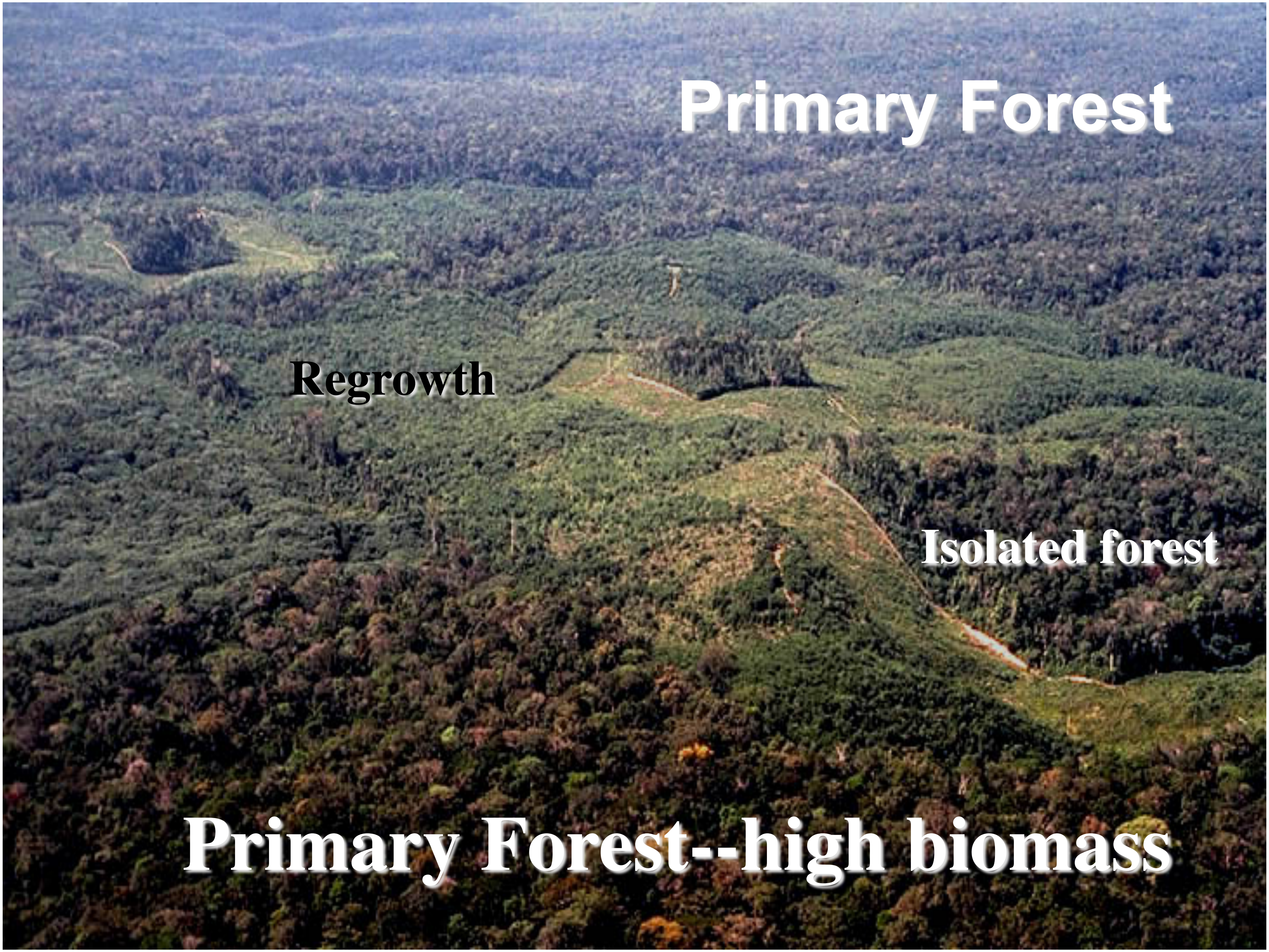
Tropical forests, biodiversity, & biomass





Igapo or Amazon Flooded Forest

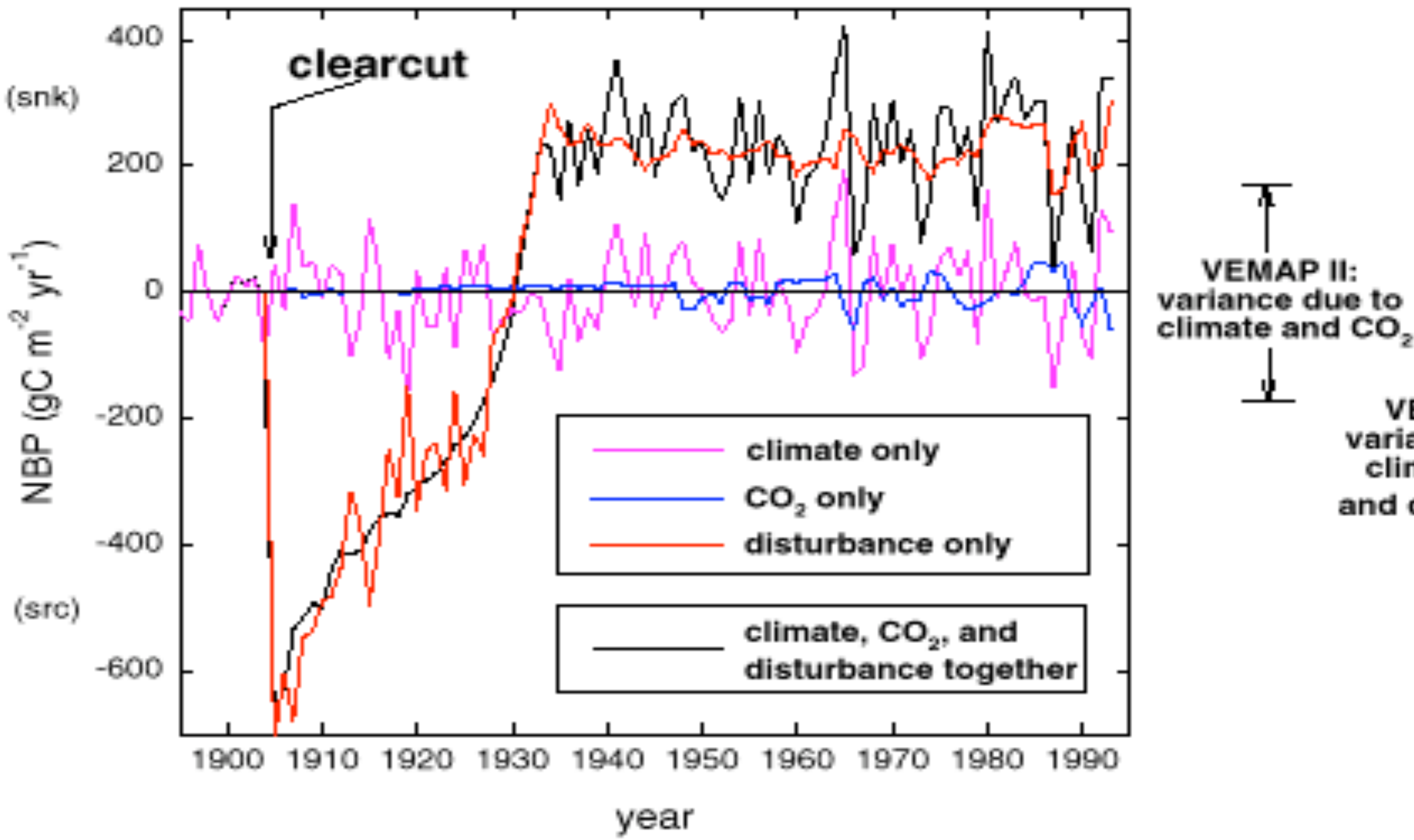

Gallery Tropical Forest


Primary Forest
Regrowth
Isolated forest
Primary Forest--high biomass

Tropical forests are cut, dried, and burned for farming

Burning after deforestation

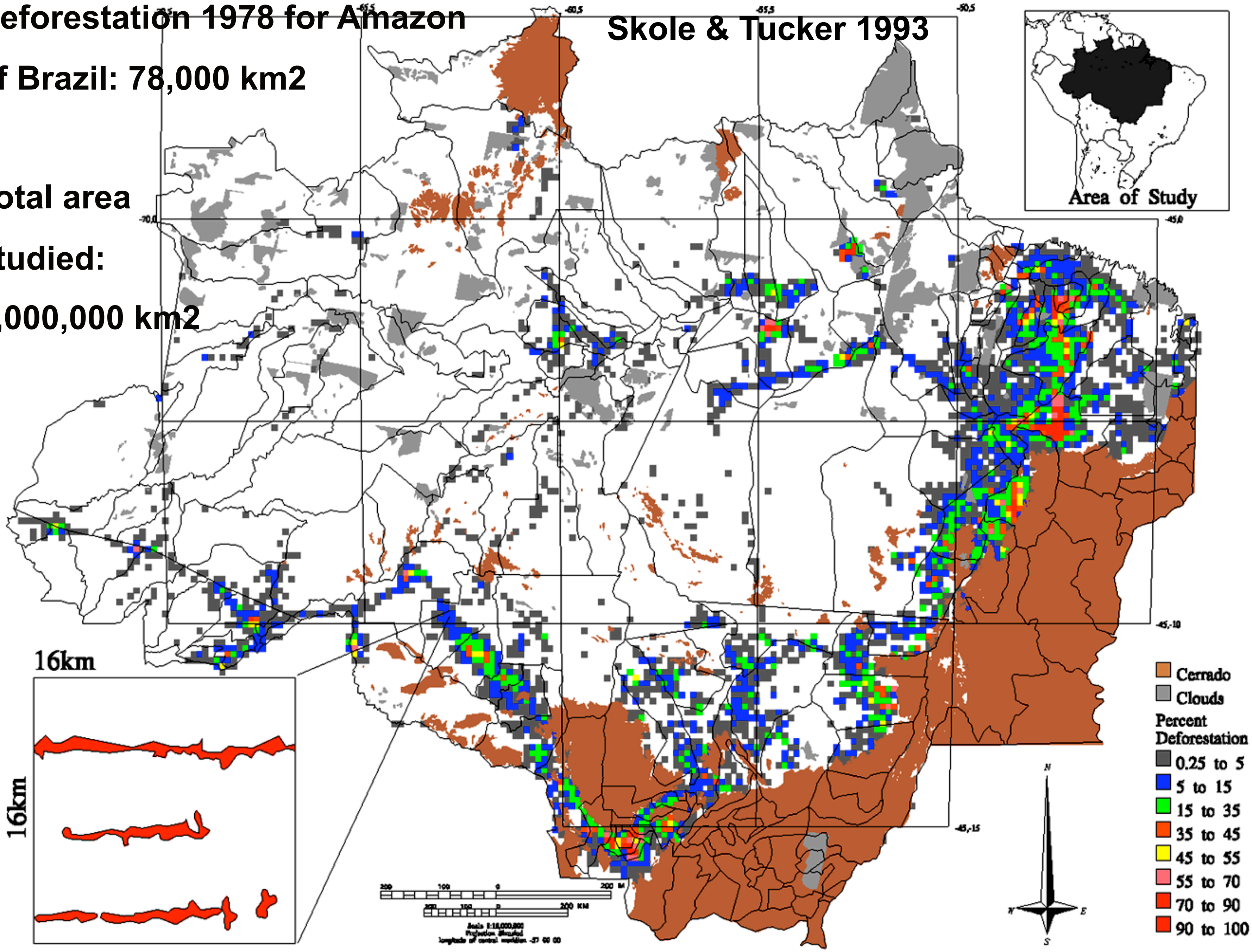
Influence of disturbance on net carbon exchange, relative to interannual climate variation and increasing CO_2



Deforestation 1978 for Amazon of Brazil: 78,000 km2

Skole & Tucker 1993

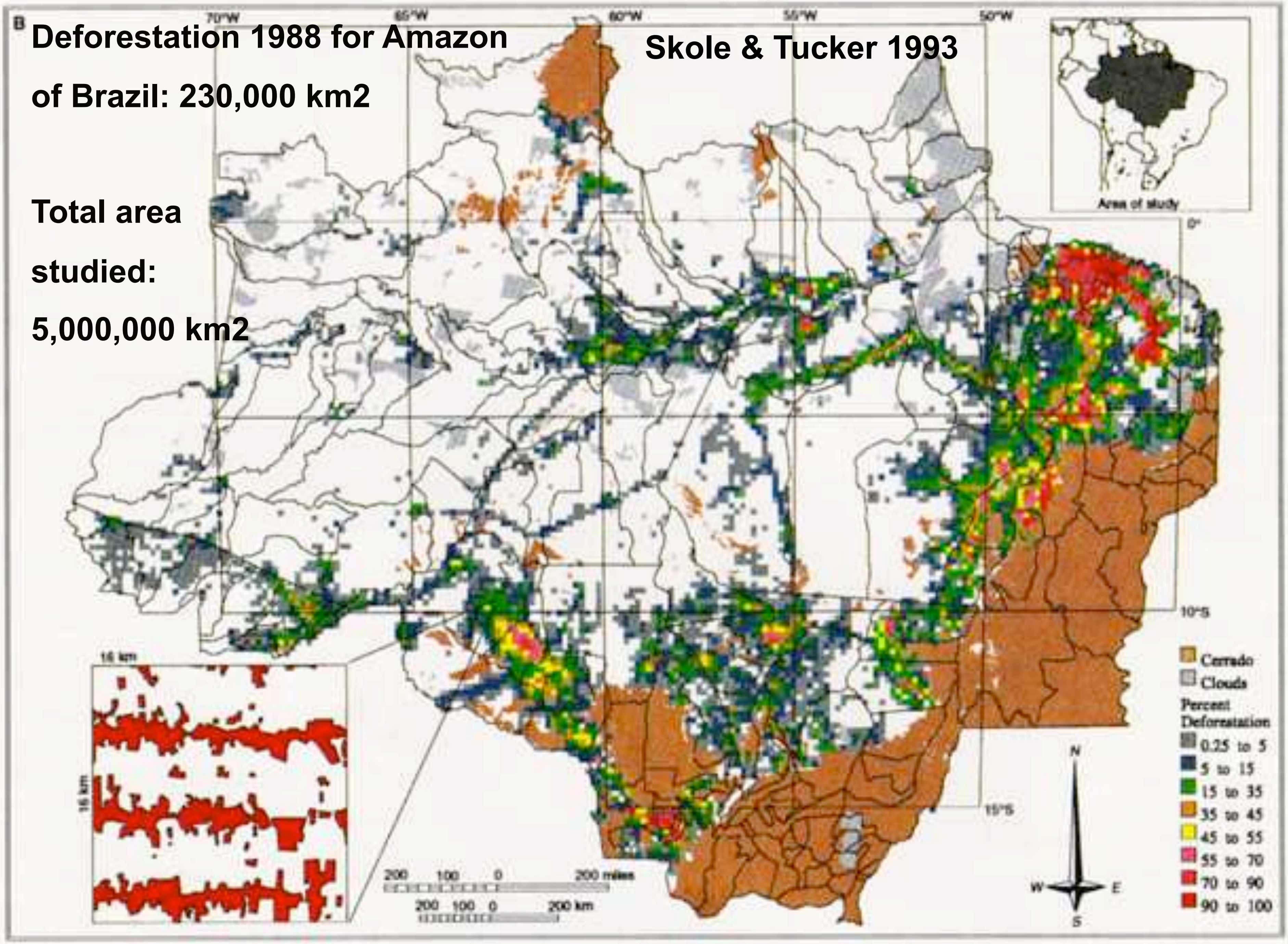
Total area studied: 5,000,000 km2



Deforestation 1988 for Amazon of Brazil: 230,000 km2

Skole & Tucker 1993

Total area studied: 5,000,000 km2

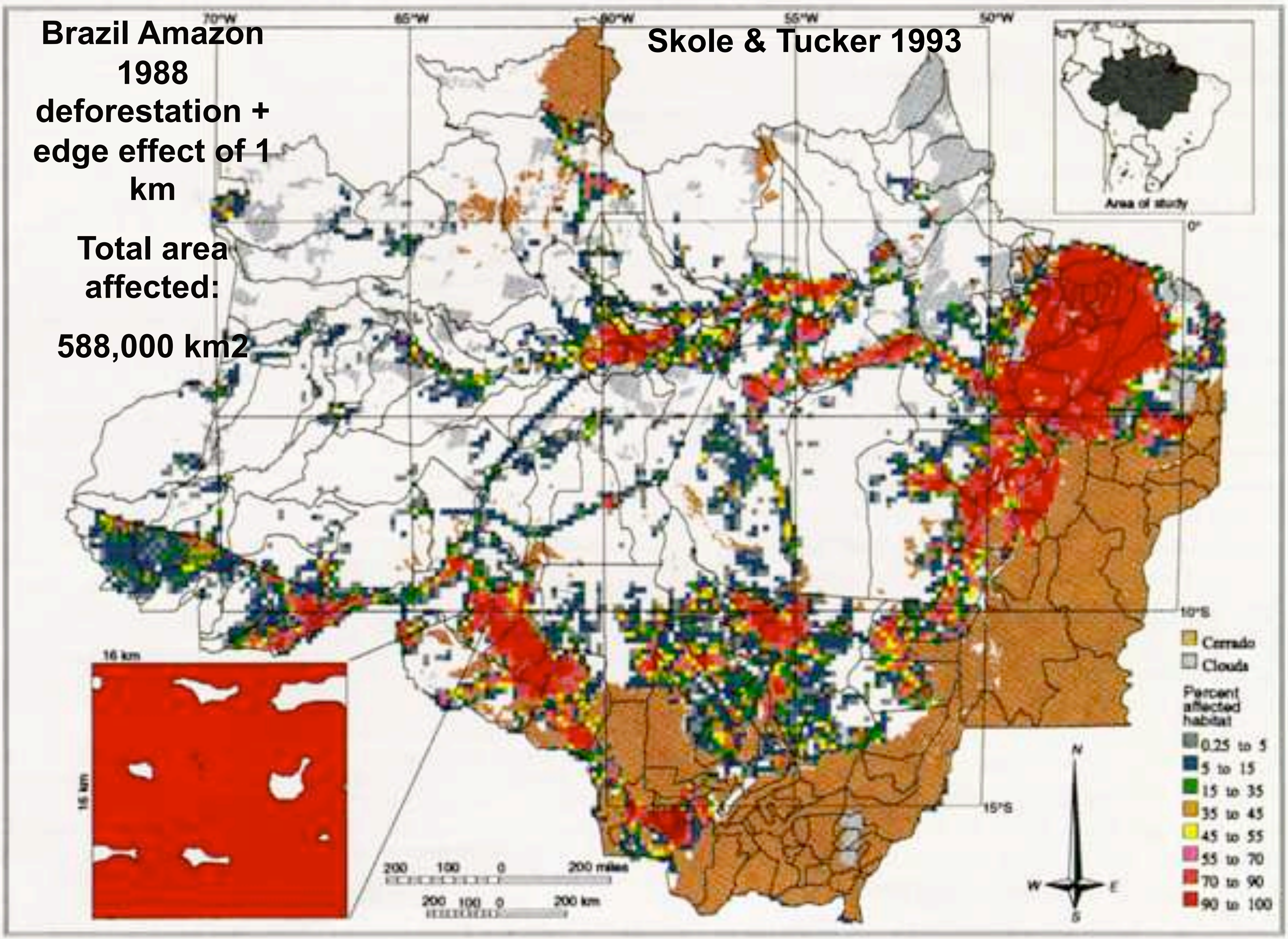


Brazil Amazon 1988 deforestation + edge effect of 1 km

Total area affected:

588,000 km2

Skole & Tucker 1993



Tropical deforestation monitoring with satellite data

- Skole and Tucker (1993) used Landsat data from 1978 and 1988 and was completed in 1992 only for Brazil – took 3 years of work.
- Hansen et al. (2007) used data from 2000 and 2005 was completed in 2007 for all tropical countries using Landsat and MODIS data – took only 2 years for much larger area.

Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data

Matthew C. Hansen[*], Stephen V. Stehman[†], Peter V. Potapov[*], Thomas R. Loveland[**‡], John R. G. Townshend[§], Ruth S. DeFries[§¶], Kyle W. Pittman[*], Belinda Arunarwati[‖], Fred Stolle[**], Marc K. Steininger[††], Mark Carroll[§], and Charlene DiMiceli[§]

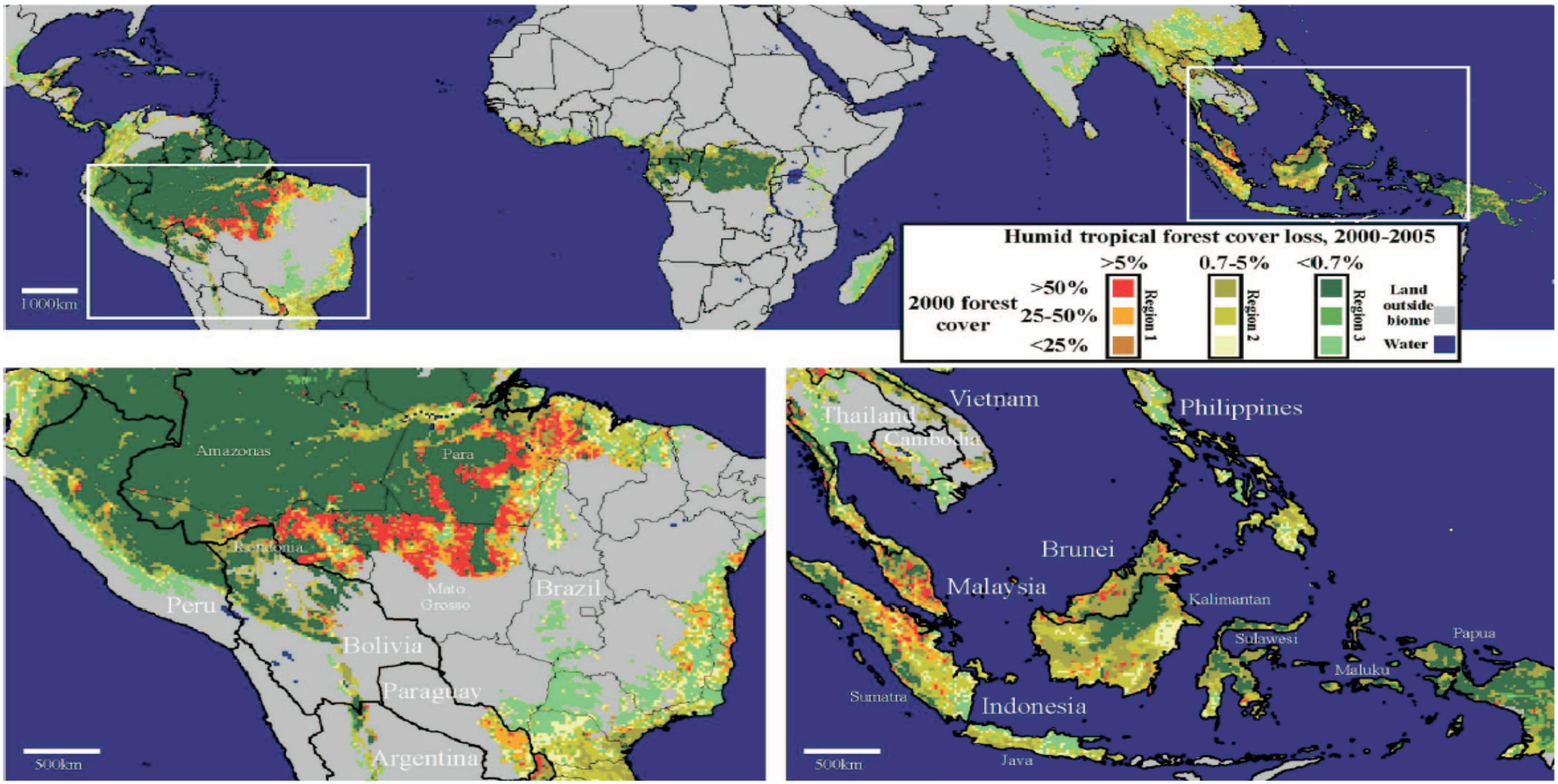
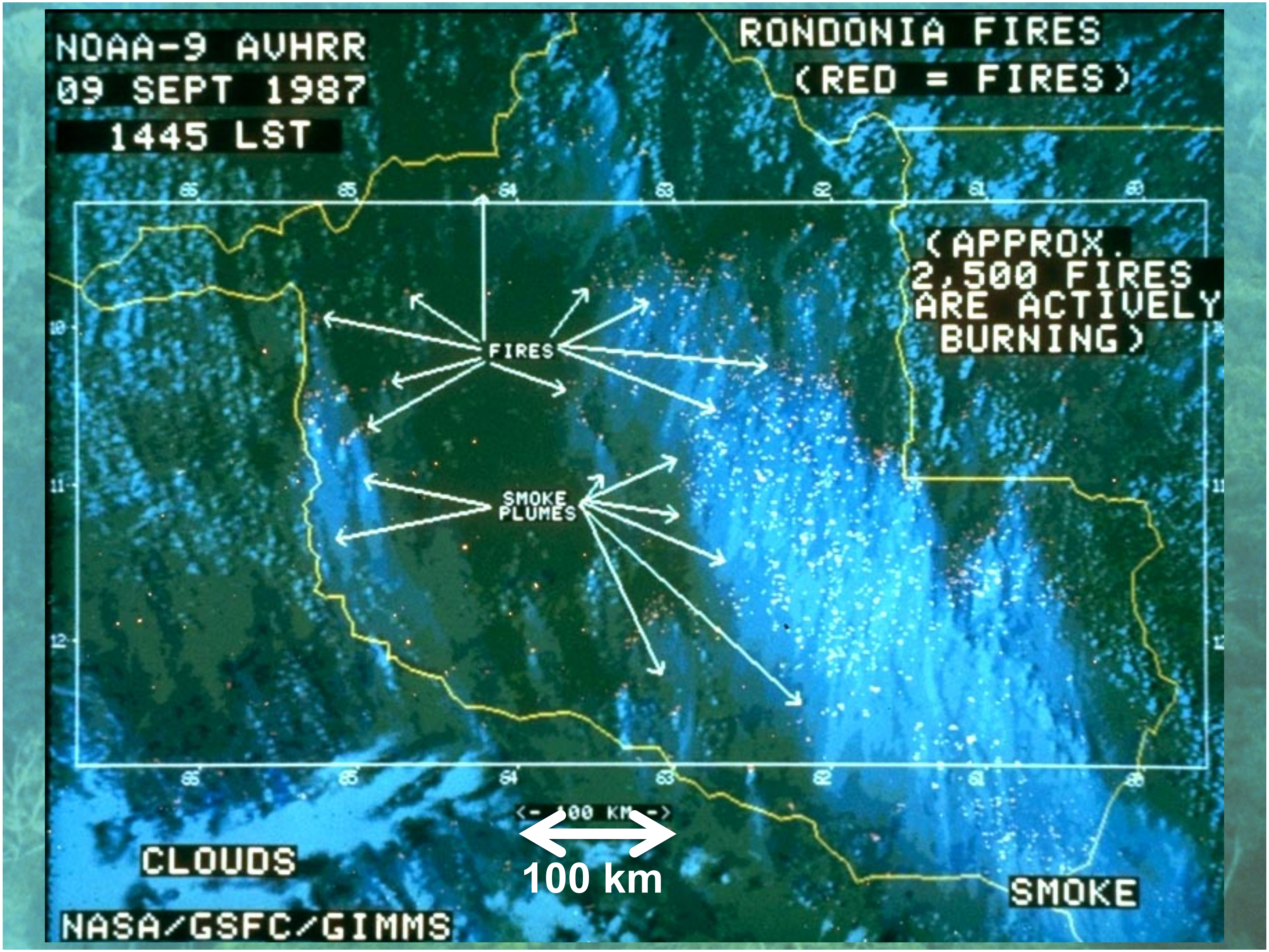


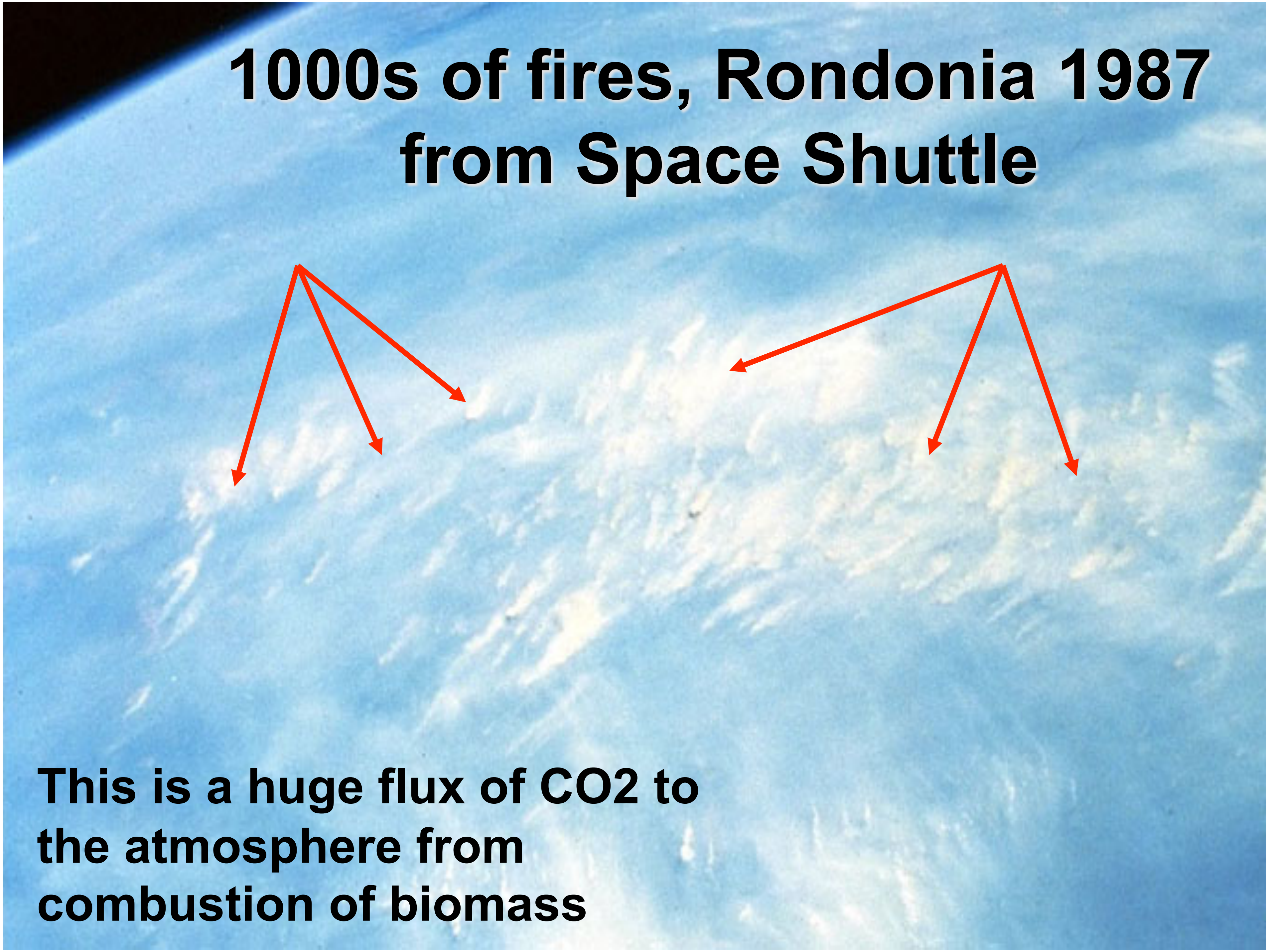
Fig. 1. Forest clearing and forest cover in the humid tropical forest biome, 2000–2005. Total forest clearing over the study period is estimated to be 27.2 million hectares (SE 2.28 million hectares). Regional variation in clearing intensity is shown: Region 1 covers 6% of the biome and contains 55% of clearing; region 2 covers 44% of the biome and contains 40% of forest clearing; and region 3 covers 50% of the biome and contains 5% of forest clearing. Data from this figure are available at http://globalmonitoring.sdstate.edu/projects/gfm.

Tropical deforestation rates (2000-2005)

- Brazil (26,000 km2/yr) and Indonesia (7,000 km2/yr) confirmed as having the highest rates of tropical deforestation.
- FAO’s Forest Resource Assessment (FRA) estimates are Brazil (31,000 km2/yr) and Indonesia (18,000 km2/yr).
- Tropical African countries have *less than one third* FAO’s FRA (2005) estimates.
- Global actual tropical deforestation rate is lower than FAO’s FRA estimate.
- Results are verifiable—data open to all.
- From Hansen et al. 2007 PNAS.

Biomass burning monitoring with satellite data

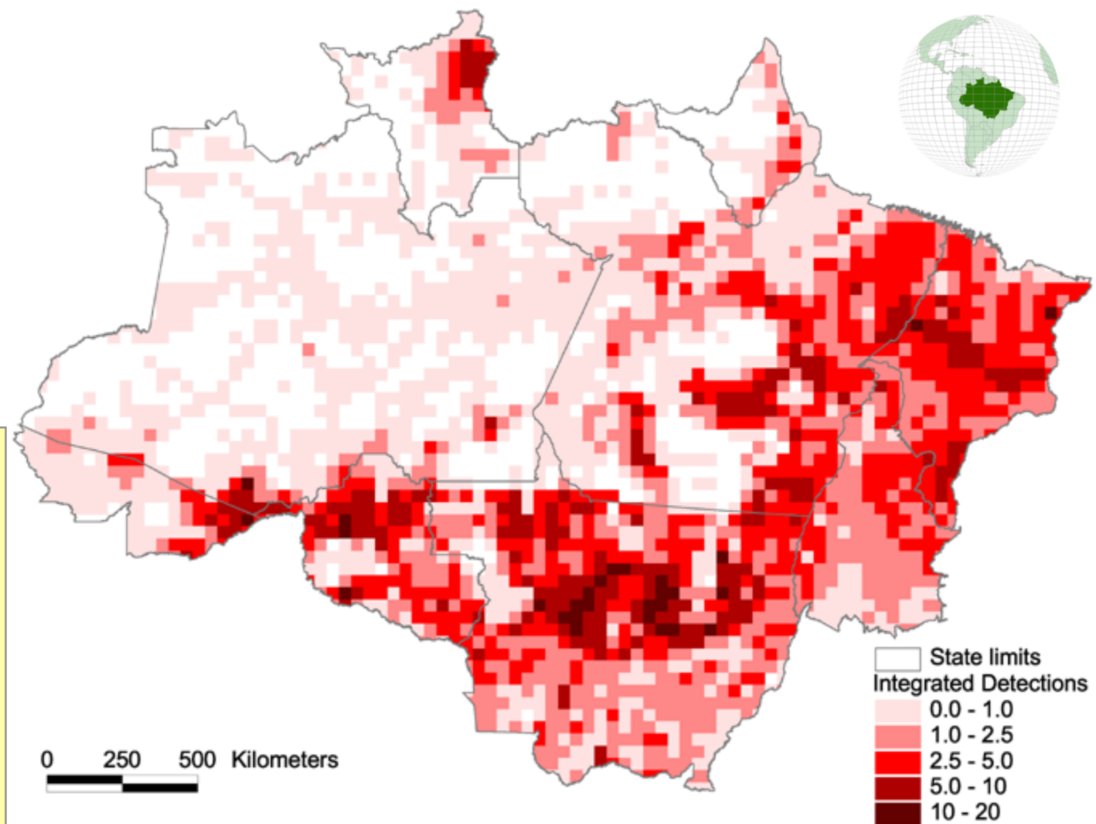

NOAA-9 AVHRR
09 SEPT 1987
1445 LST
RONDONIA FIRES
(RED = FIRES)
(APPROX. 2,500 FIRES ARE ACTIVELY BURNING)
FIRES
SMOKE PLUMES
100 km
CLOUDS
SMOKE
NASA/GSFC/GIMMS


1000s of fires, Rondonia 1987
from Space Shuttle
This is a huge flux of CO2 to
the atmosphere from
combustion of biomass

Monitoring Vegetation Fires in Amazonia

Schroeder et al

Optimizing the combined use of MODIS and GOES fire detection data for Amazonia



Integrated fire product for Brazilian Amazonia using 2005 MODIS and GOES data showing average number of detection days per year.

Publications:

1. Schroeder, W., Prins, E., Giglio, L., Csiszar, I., Schmidt, C., Morisette, J., and D. Morton (2008). Validation of GOES and MODIS active fire detection products using ASTER and ETM+ data. *Remote Sensing of Environment*, 112 (5), 2711-2726, doi:10.1016/j.rse.2008.01.005.

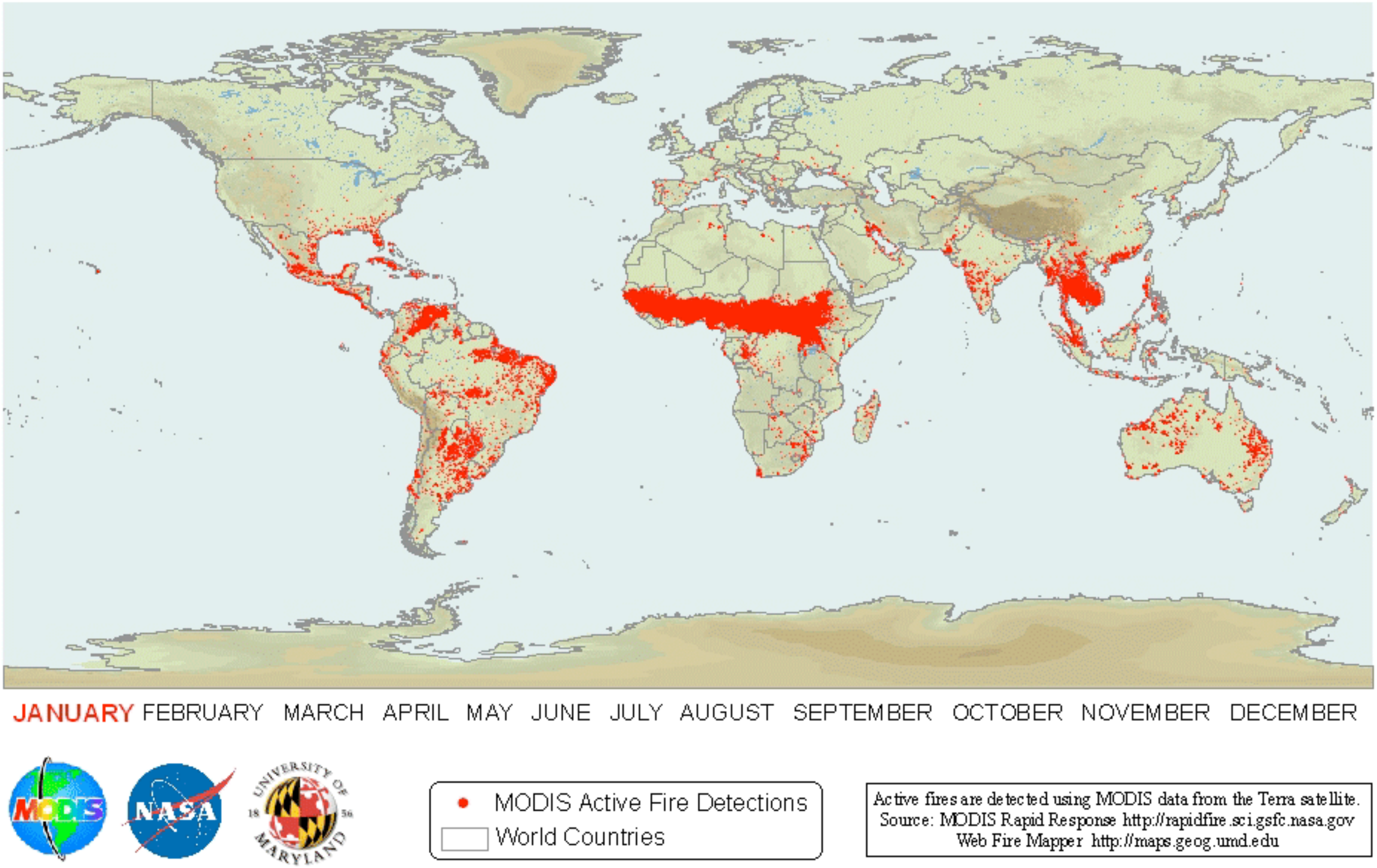
2. Schroeder, W., Csiszar, I., and Morisette, J. (2008). Quantifying the impact of cloud obscuration on remote sensing of active fires in the Brazilian Amazon. *Remote Sensing of Environment*, 112, 456-470, doi:10.1016/j.rse.2007.05.004.

3. Schroeder, W., Morisette, J. T., Csiszar, I., Giglio, L., Morton, D., and Justice, C. (2005). Characterizing vegetation fire dynamics in Brazil through multisatellite data: Common trends and practical issues. *Earth Interactions*, 9, Paper 13.

4. Morisette, J.T., Giglio, L., Csiszar, I., Setzer, A., Schroeder, W., Morton, D., and Justice, C. (2005), Validation of MODIS active fire detection products derived from two algorithms. *Earth Interactions*, 9, Paper 9.

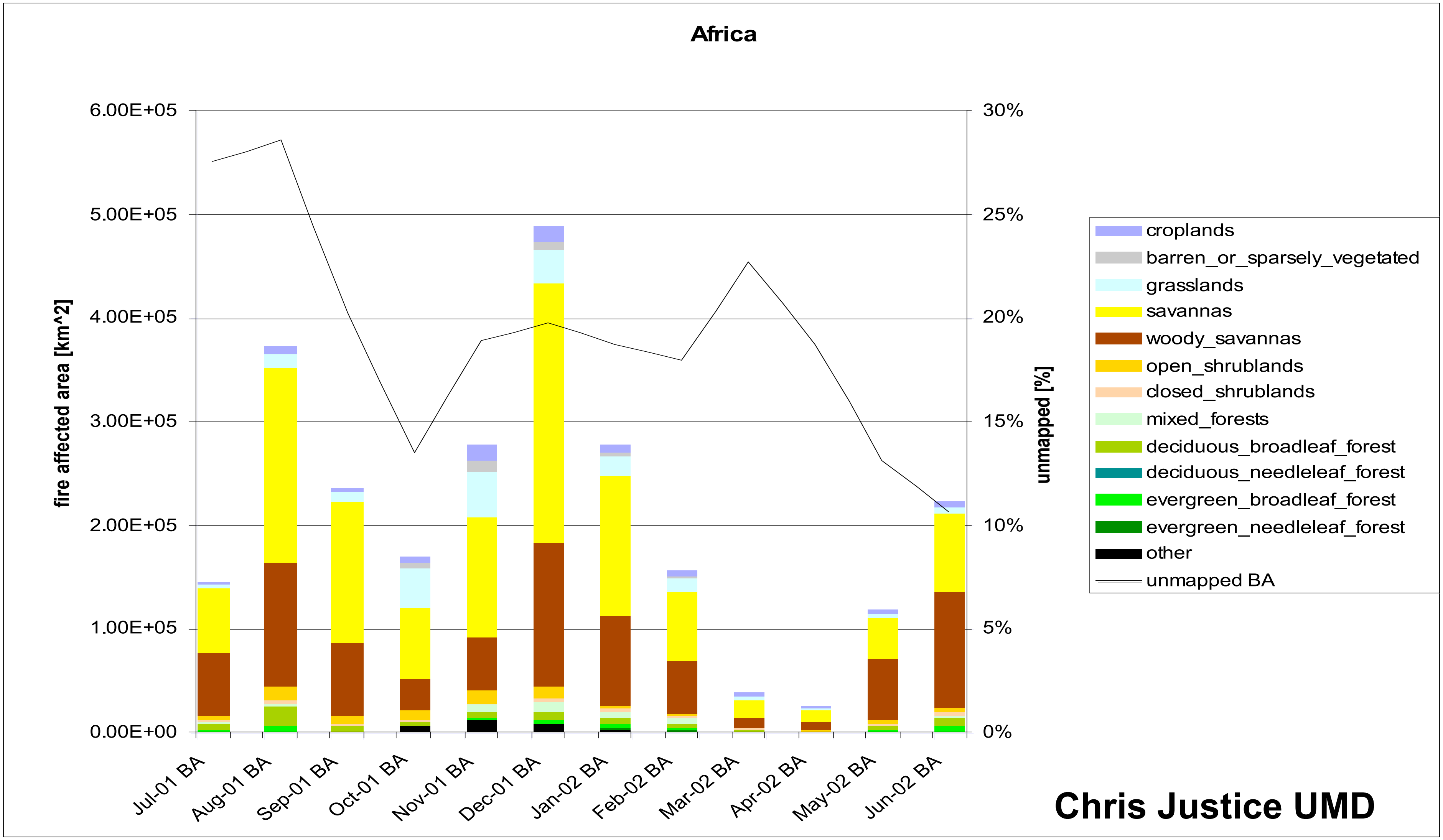
Importance of Fire for Biomass burning & Land Cover Change

MODIS Rapid Response Fire Detections for 2005



Active fires are detected using MODIS data from the Terra satellite.
Source: MODIS Rapid Response http://rapidfire.sci.gsfc.nasa.gov
Web Fire Mapper http://maps.geog.umd.edu

From MODIS excellent fire data that is used for carbon emissions

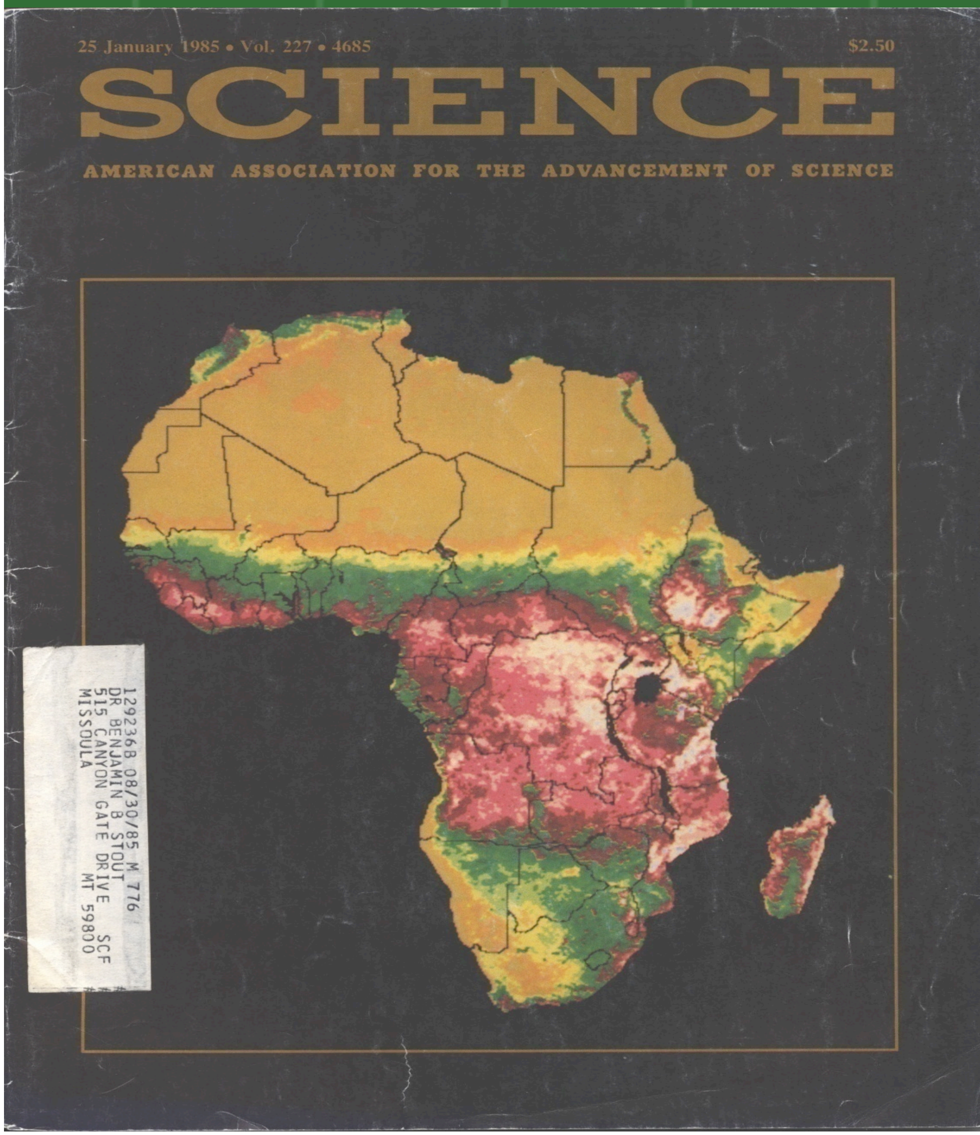


Chris Justice UMD

Land use and land cover change – a key component of climate

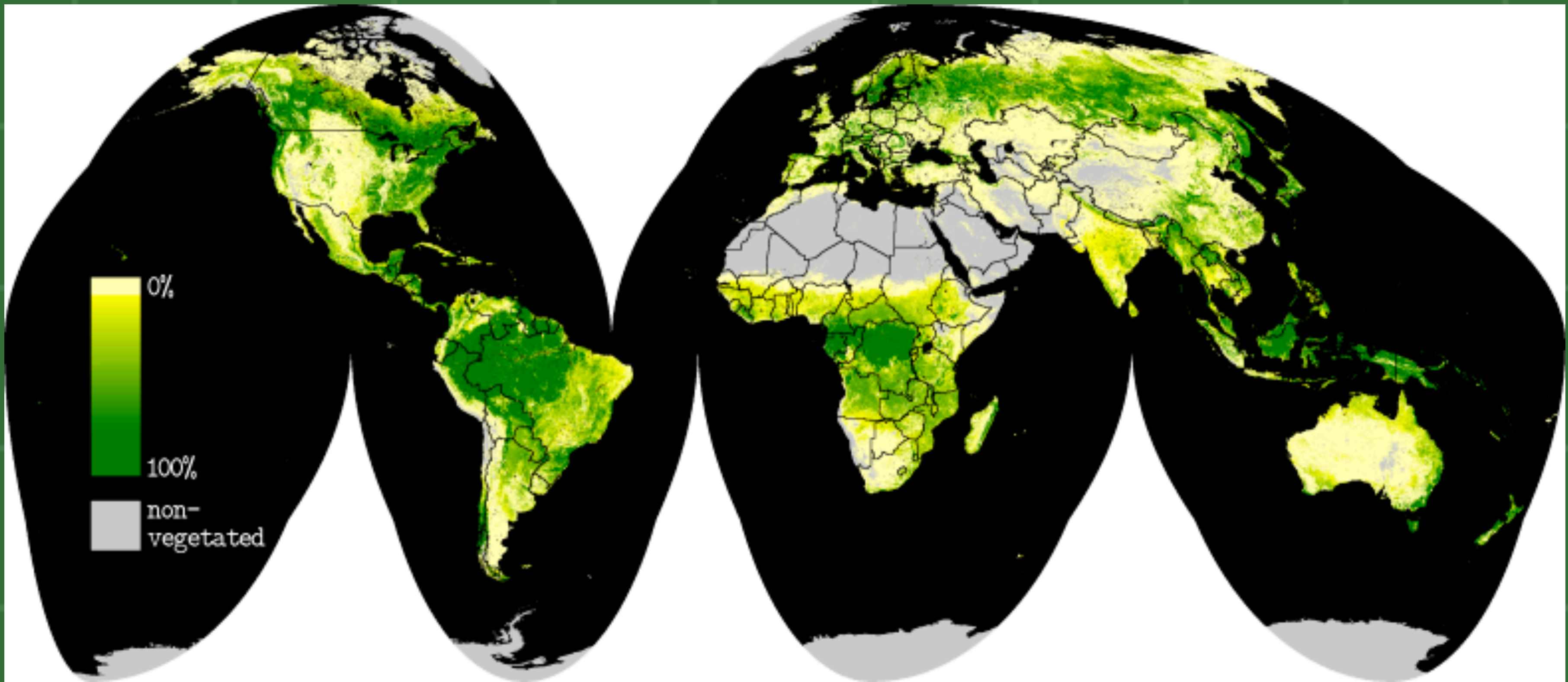
- If all our forests were cut and replaced by crops or grasslands, atmospheric CO2 concentrations would rise by 300 ppm!
- If forest soils are disturbed by land use change, the soil carbon would oxidize and raise atmospheric CO2 levels by an additional 700 ppm!
- .. land use and land cover change are central to climate

Land use and land cover change – critical for the carbon cycle



Tucker and Townshend's 1985 first work on land use and land cover change mapping at continental scale. 10 classes and used one year of daily 4 km data. Map grid cells at 8 km.

Vegetation Continuous Fields produced by year from MODIS at 250 m

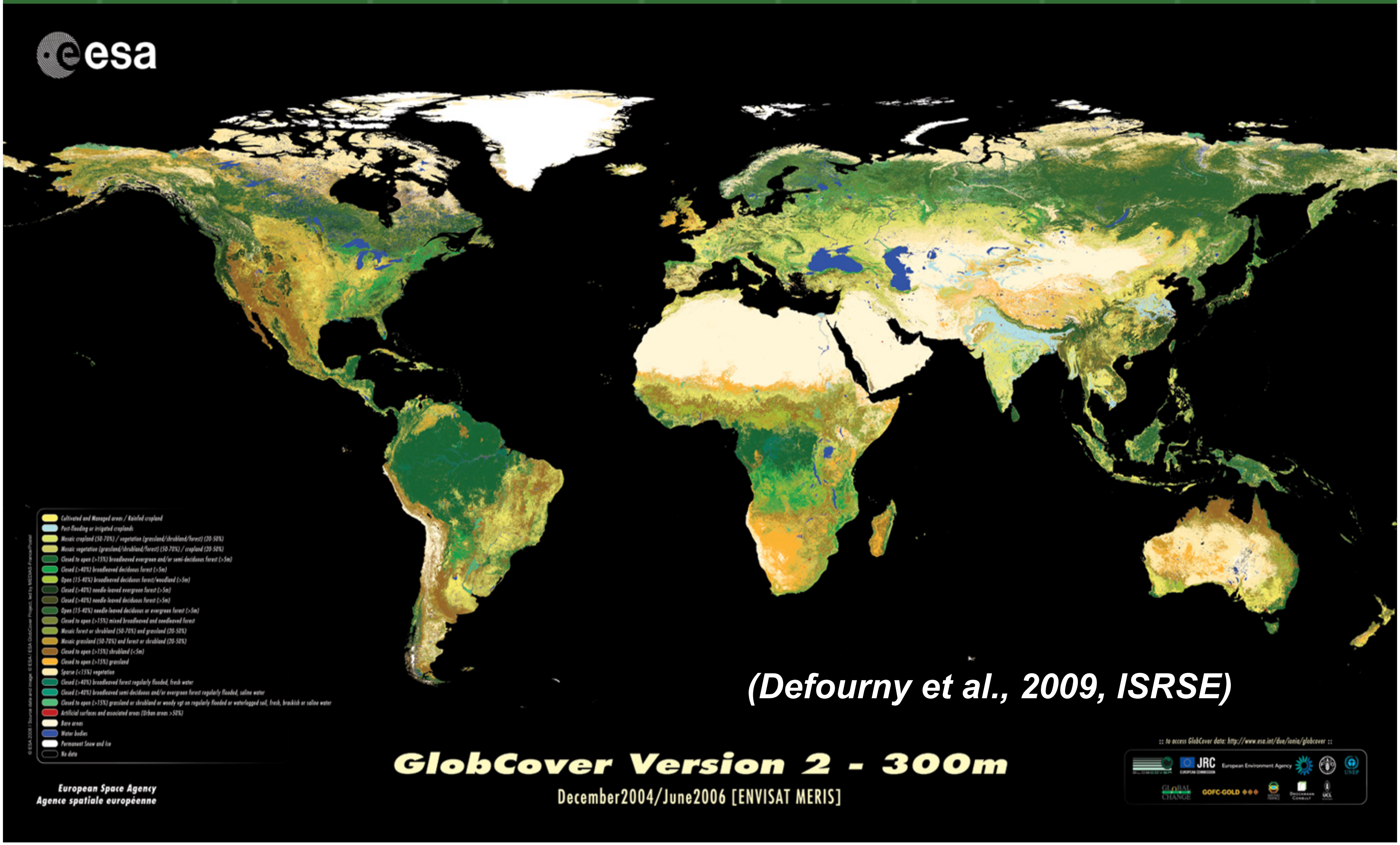


Vegetation Continuous Fields Percent tree cover from MODIS year 2001.

Slide from J. Townshend, UMd

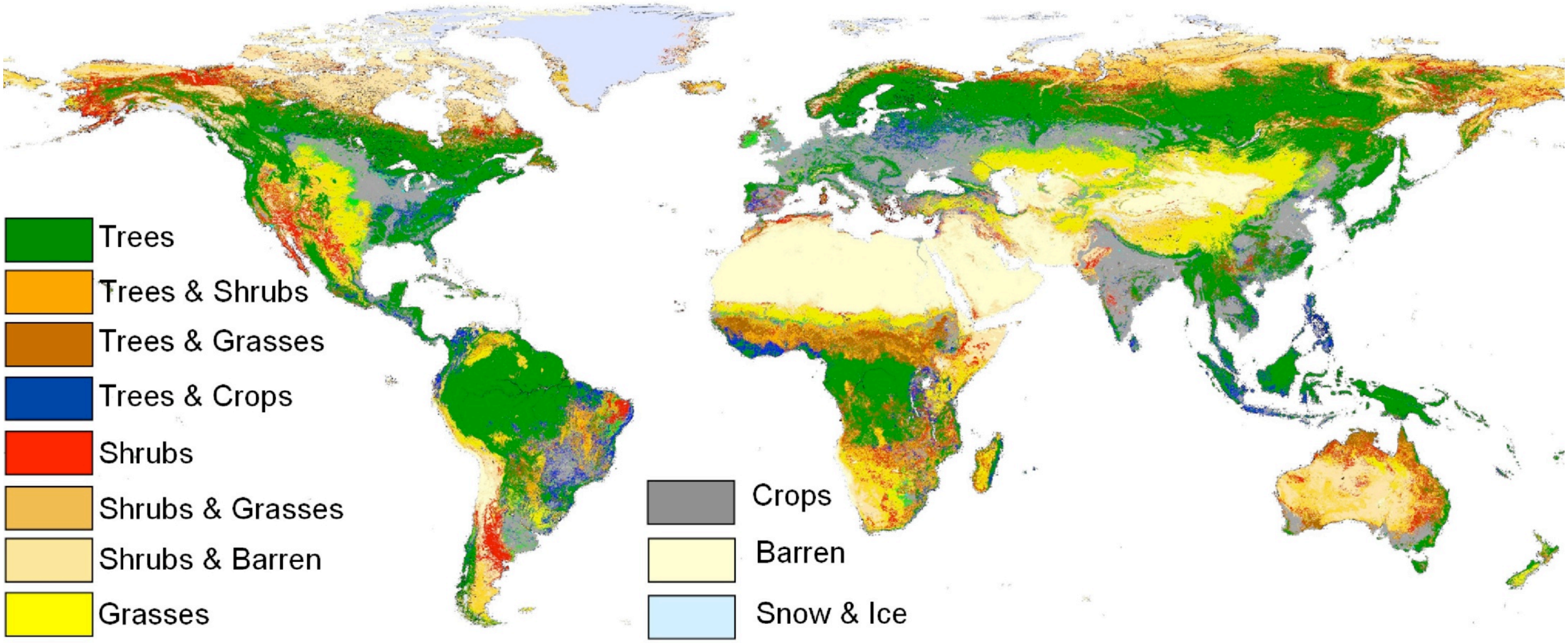
UNIVERSITY OF MARYLAND 18 56

GlobCover Land cover v. 2.2. 19 months of data (2005-2006), at 300 m, with 25 classes



(Defourny et al., 2009, ISRSE)

SYNMAP – a synthesis of existing global LC maps to provide a targeted and improved LC map for carbon cycle modelling



Slide from M. Herold

GOFC-GOLD

Using satellite data for monitoring vegetation phenology

- Changes in vegetation phenology (onset, length of growing season) can be subtle but have significant implications for:

  landscape carbon and water budgets

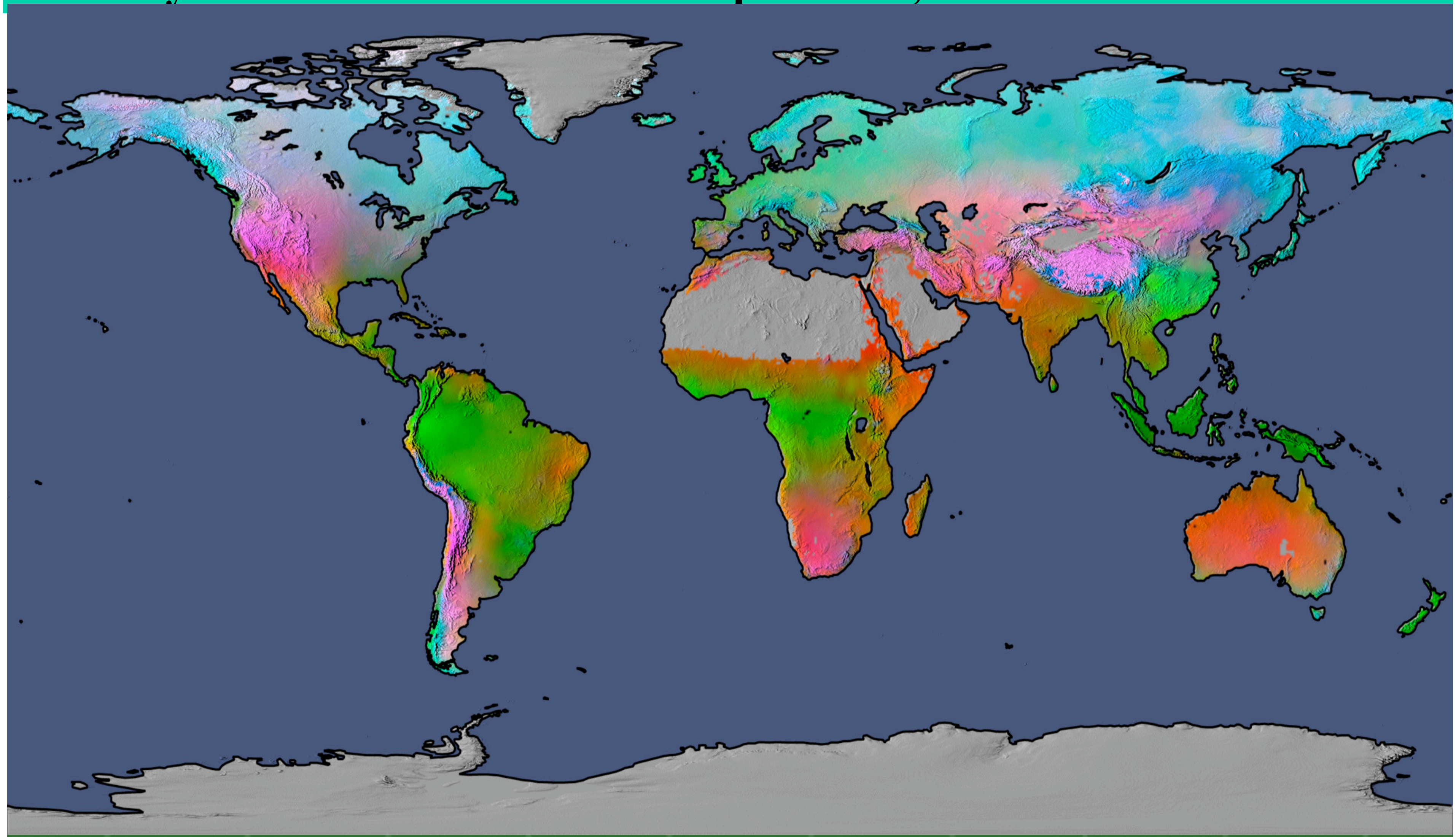
  crop yields

  biodiversity

  migration

Regular satellite data are ideal for monitoring phenology

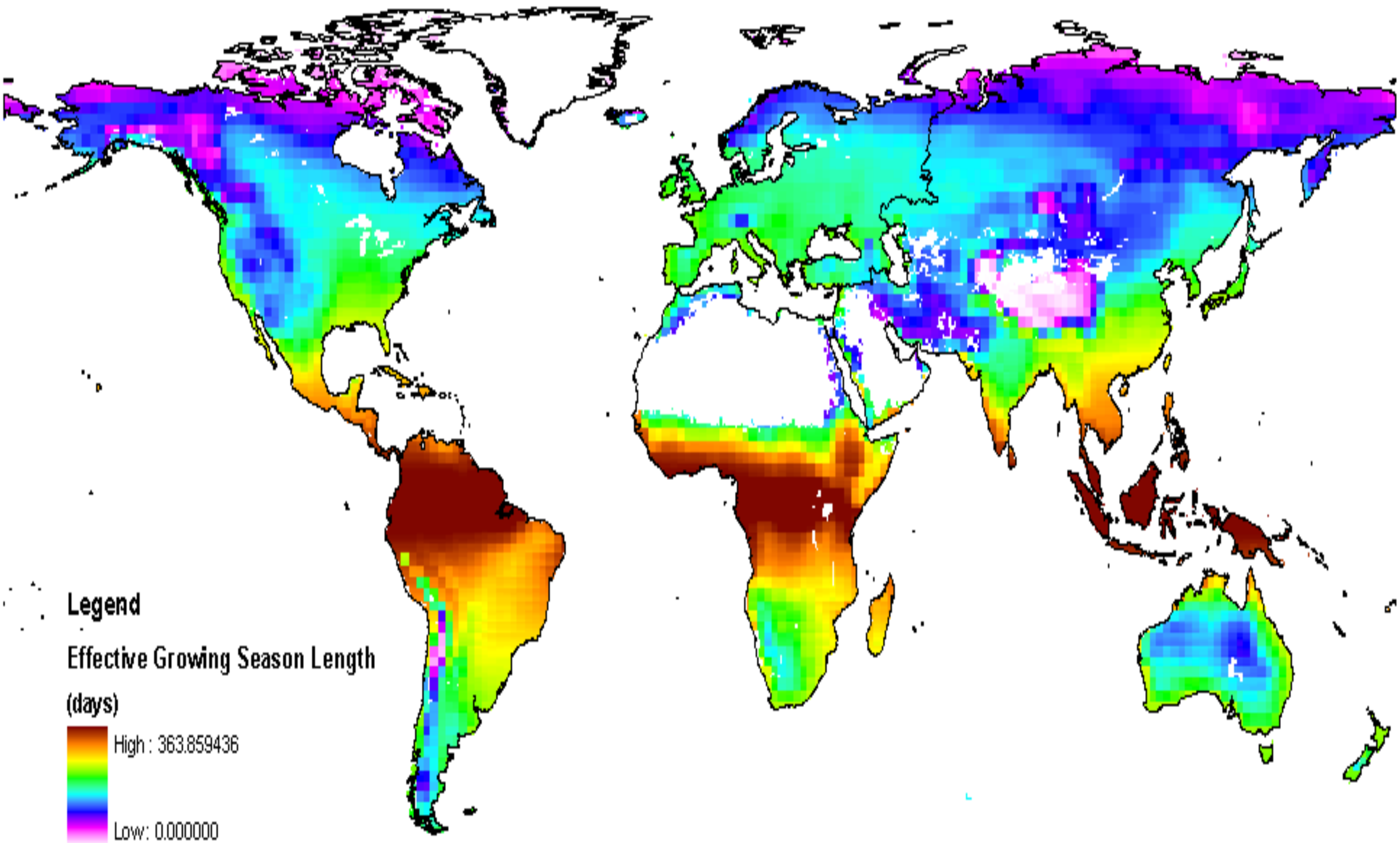
Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.



Water = 40%, Temperature = 33%, Radiation = 27%

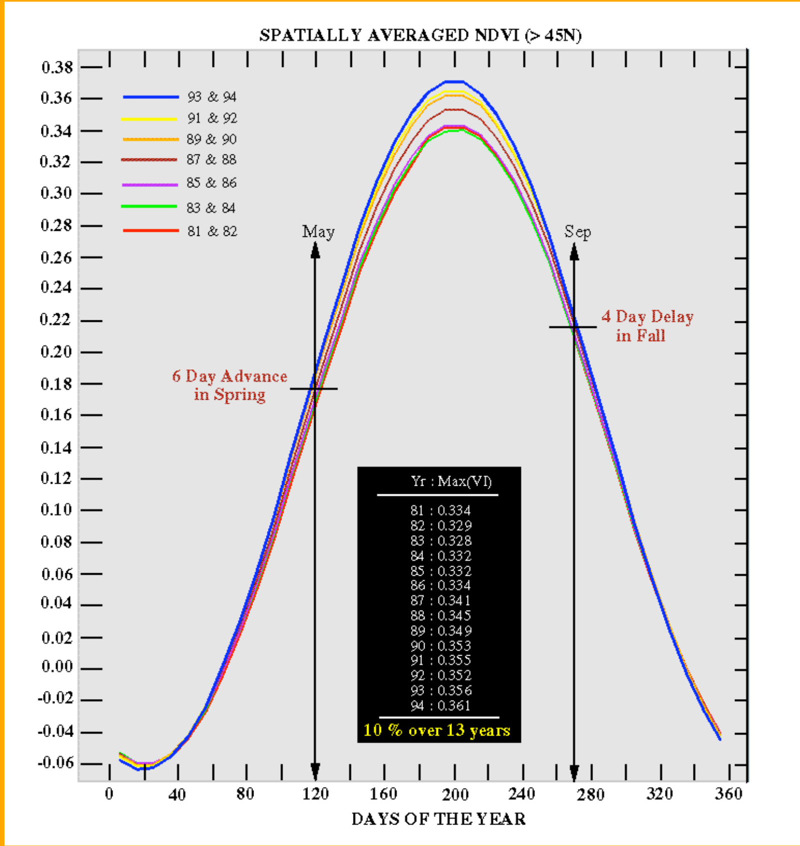
Nemani et al. 2003
Running et al 2004

Global Effective Growing Season Length



Detecting changes in growing seasons

Analyses of both GIMMS (v0) and PAL (v2) data for the period 1981 to 1994 suggest that -

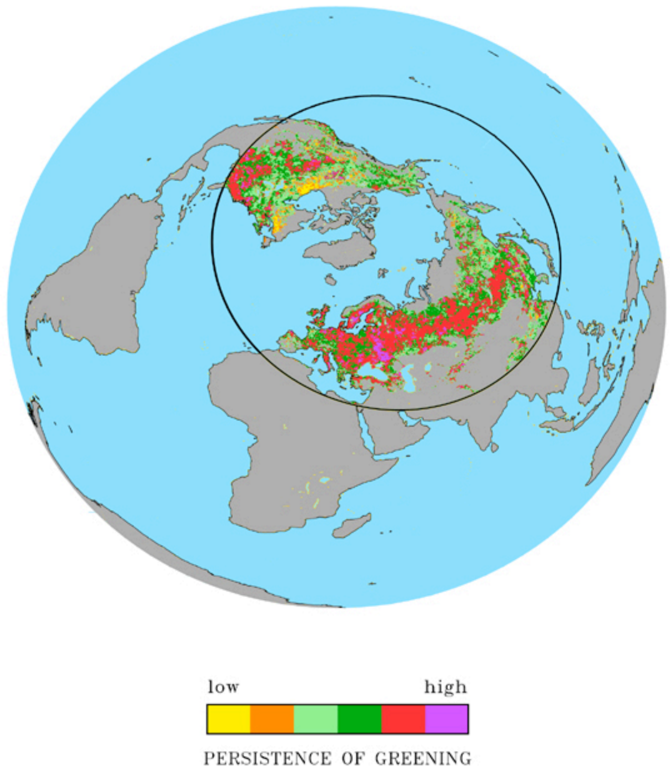


- NDVI averaged over the peak boreal growing season months of July and August increased by 10%
- The timing of spring green-up advanced by about 6 days
- Growing season duration increased by about 10 days

The satellite data are concordant with an increase in the the amplitude of the seasonal cycle of atmospheri co2 exceeding 20% since the early 1970s, and an advance in the timing of the draw-down of co2 in spring and early summer of up to 7 days (Keeling et al., Nature, 382:146-149, 1996)

From Myneni et al. (Nature, 386:698-701, 1997):

Persistence of greening



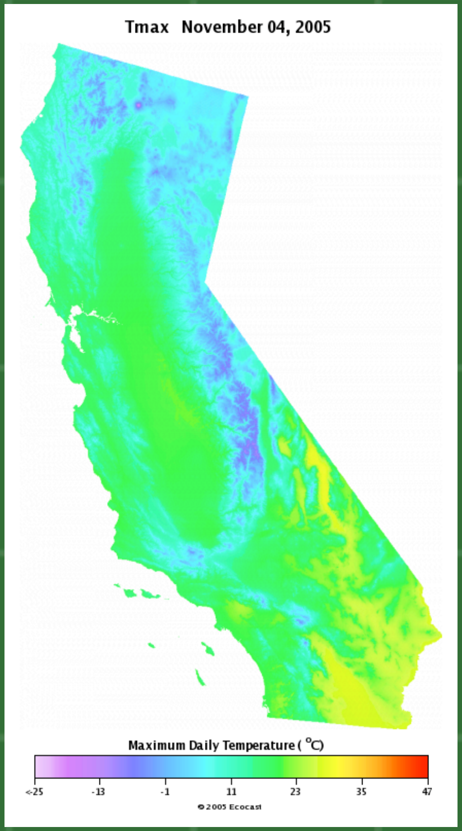
Analyses of pixel-based persistence indices from GIMMS (v1) NDVI data for the period 1981 to 1999 indicate that -

- About 61% of the total vegetated area between 40N-70N in Eurasia shows a persistent increase in growing season NDVI over a broad contiguous swath of land from Central Europe through Siberia to the Aldan plateau, where almost 58% (7.3 million km2) is forests and woodlands

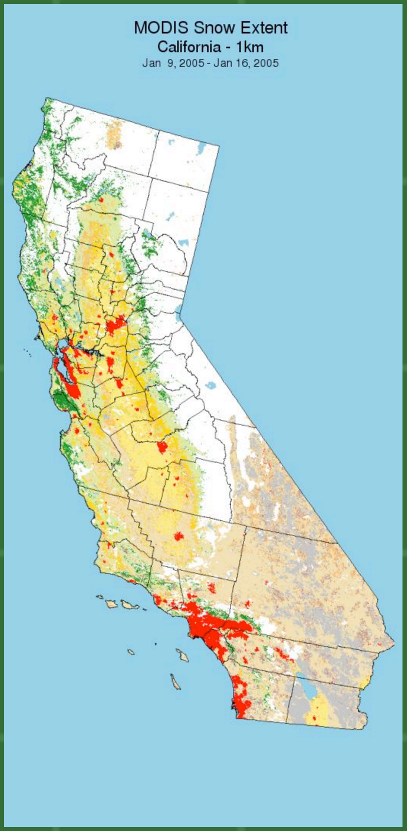
From Zhou et al., (JGR, 106(D17):20069-20083, 2001)

Monitoring growing season dynamics

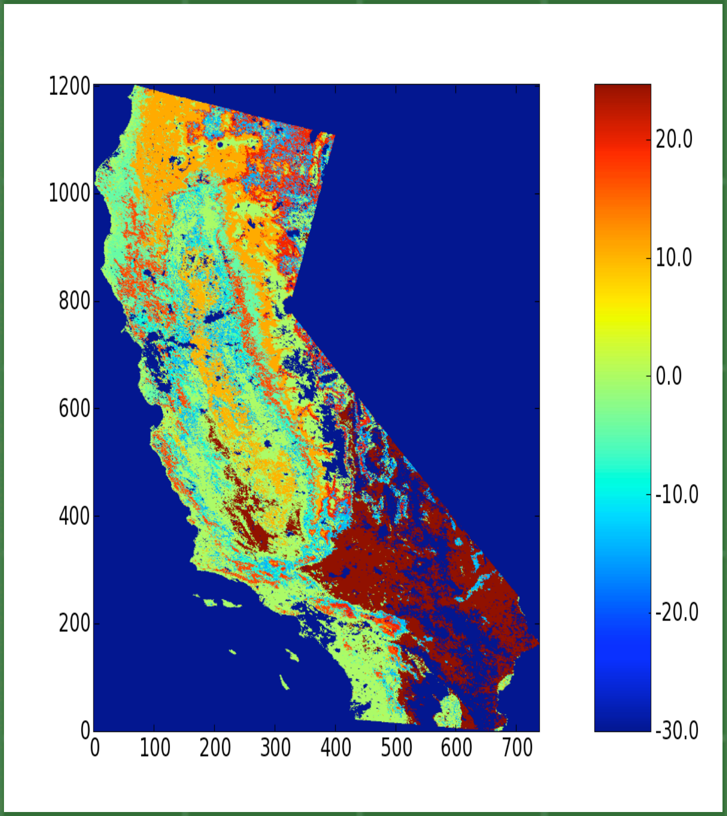
Air Temperature

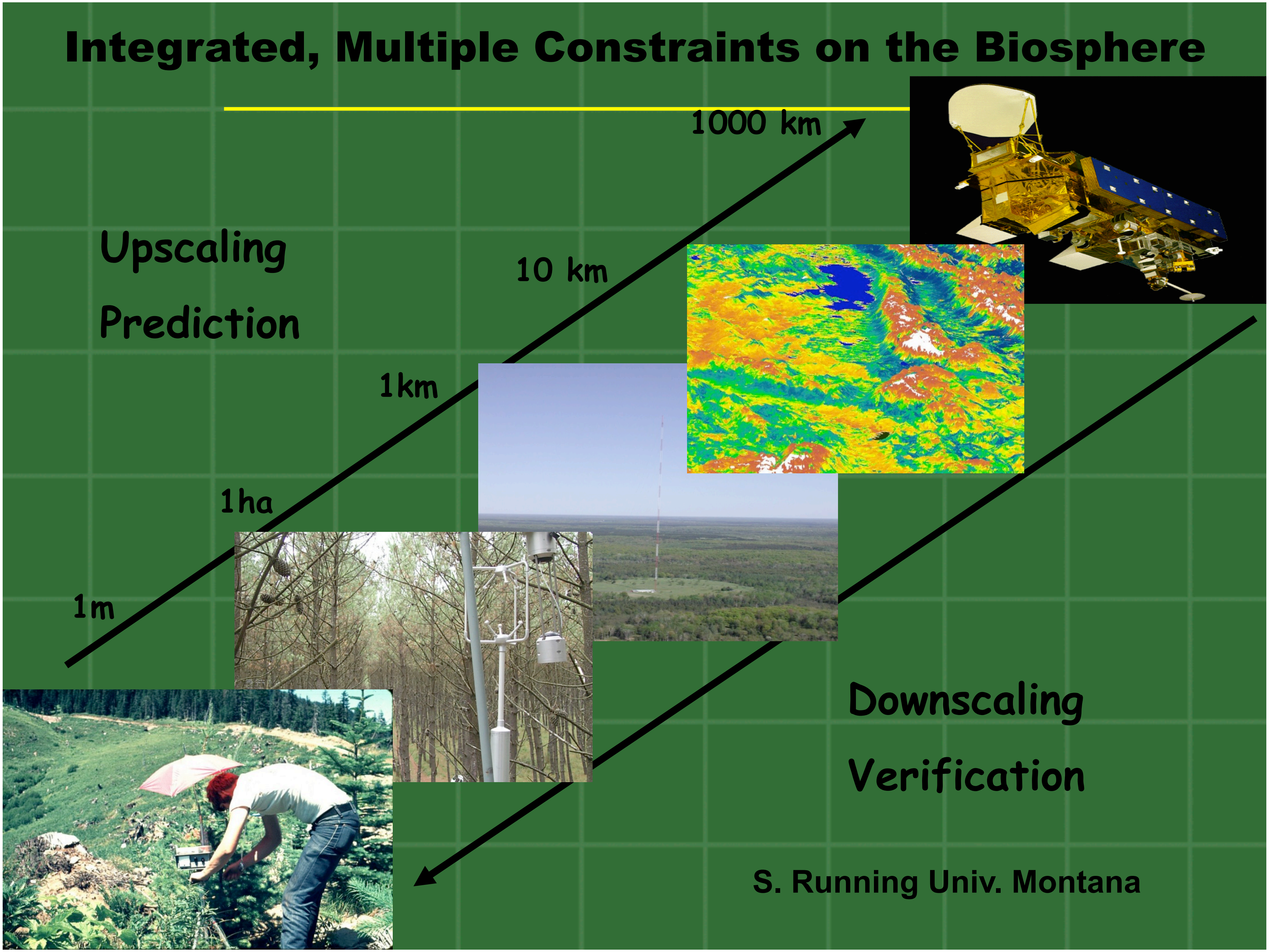


Snow cover

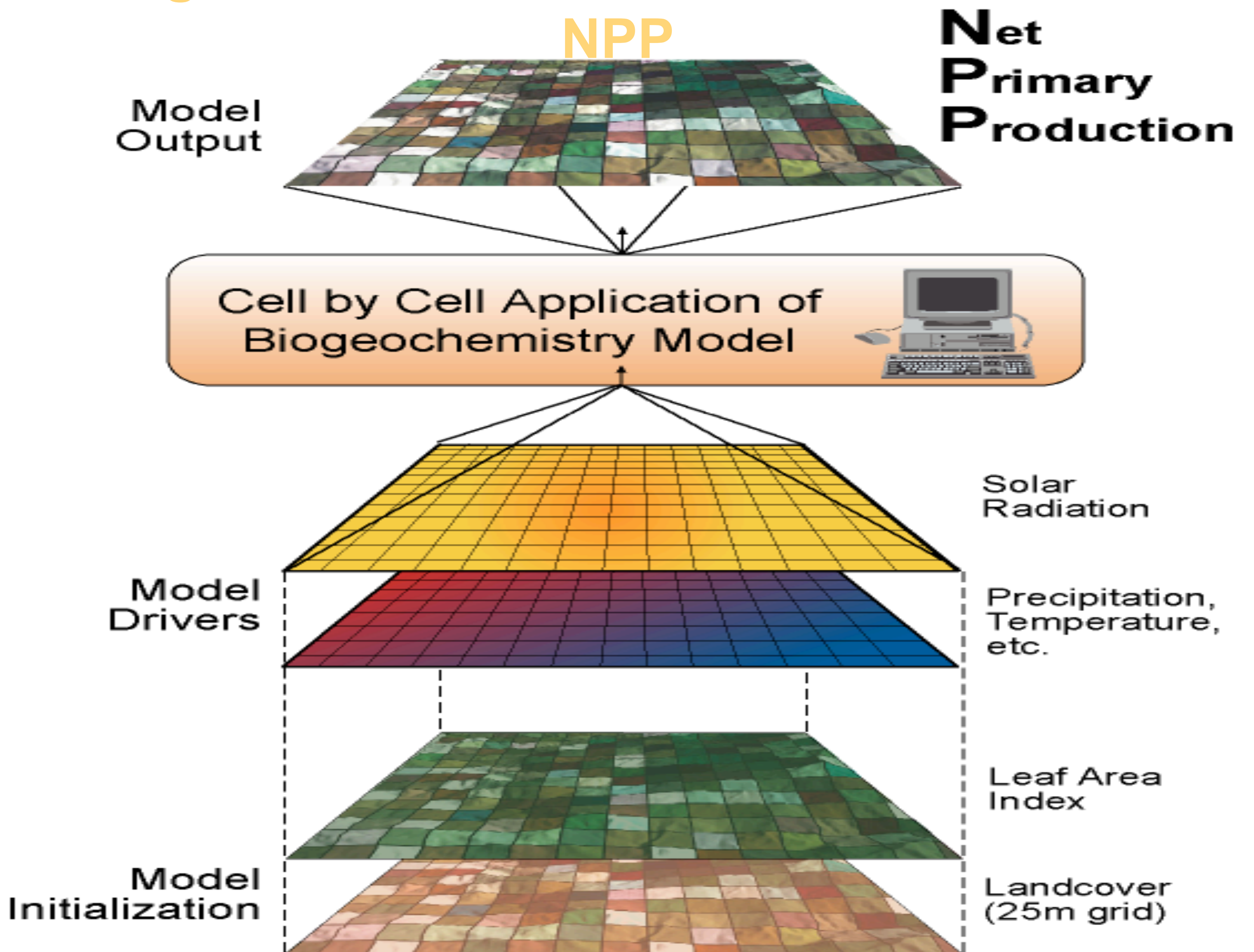


Changes in onset (days)



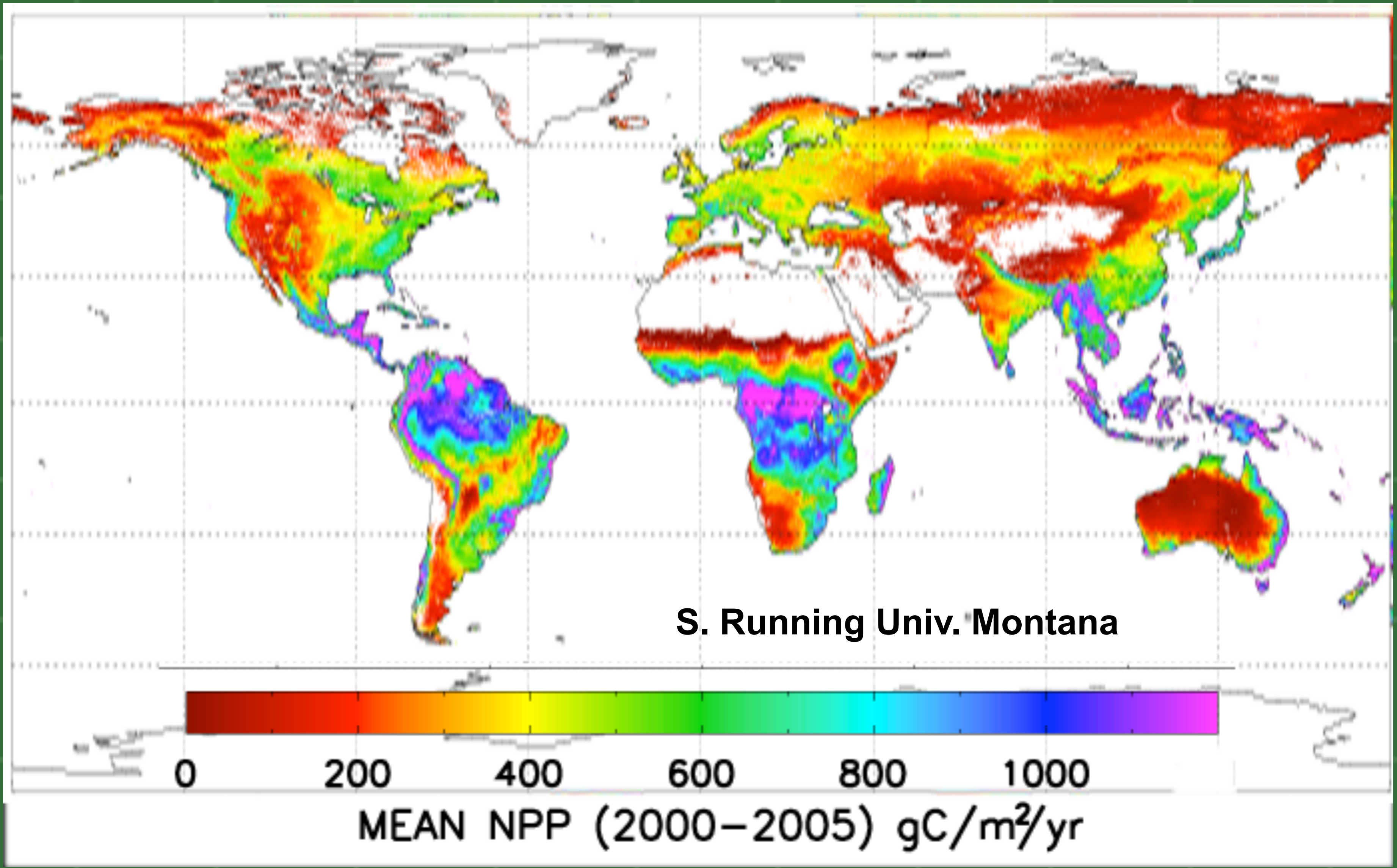

Integrated, Multiple Constraints on the Biosphere
1000 km
10 km
1km
1ha
1m
Upscaling
Prediction
Downscaling
Verification
S. Running Univ. Montana

Using satellite data and models to simulate NPP

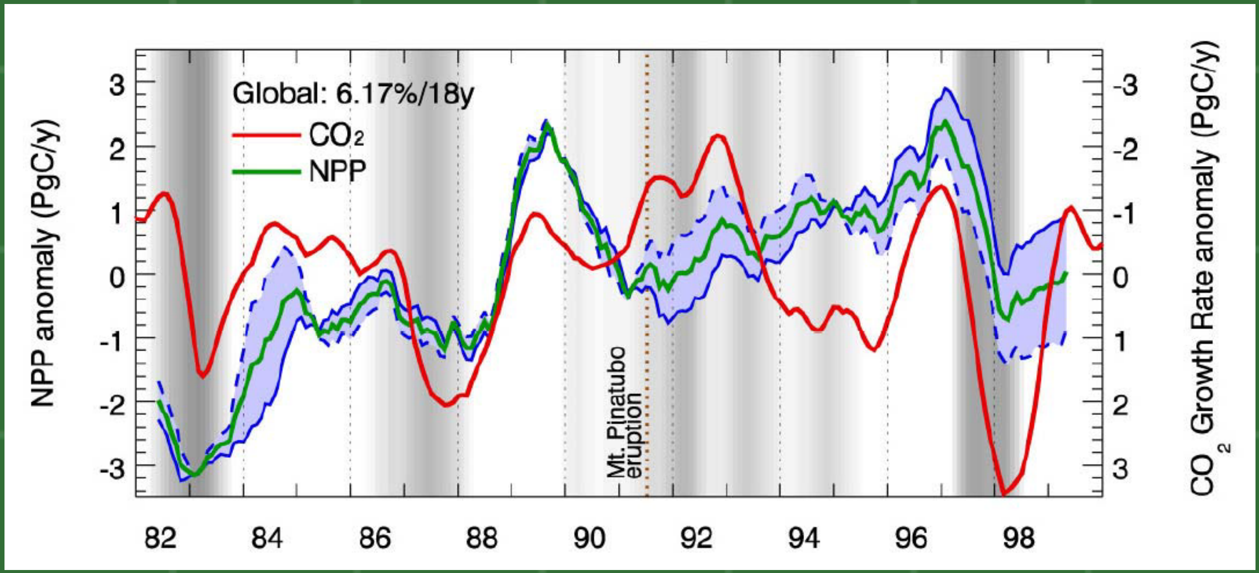


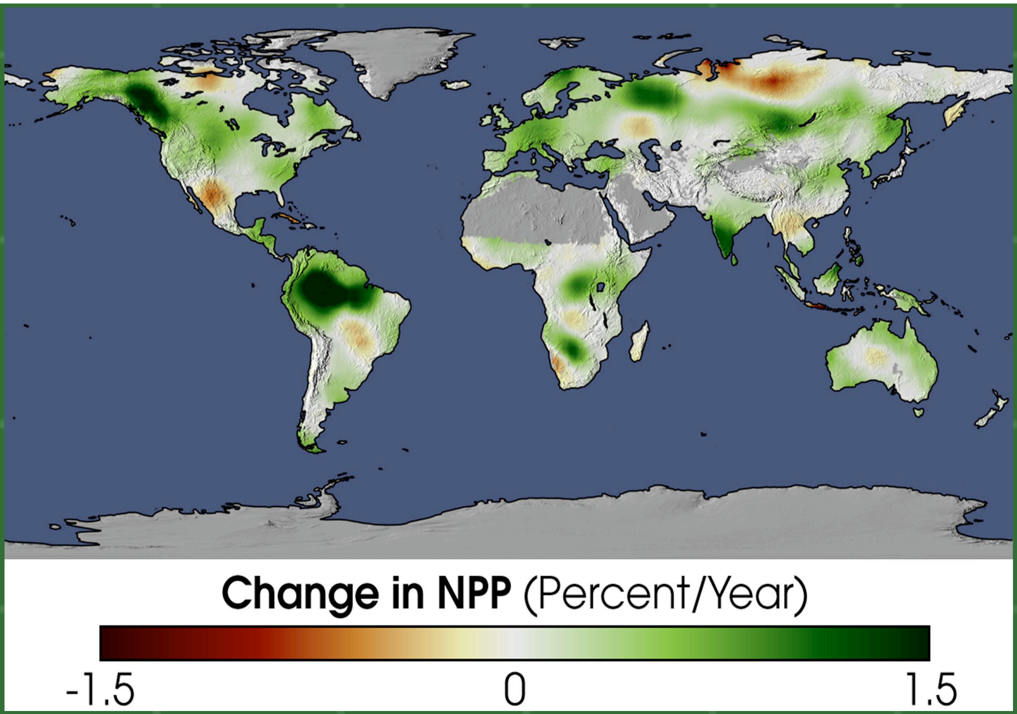
S. Running Univ. Montana

Mean NPP estimated for 140 million 1km2 cells



Trends and variability in global NPP, 1982-1999





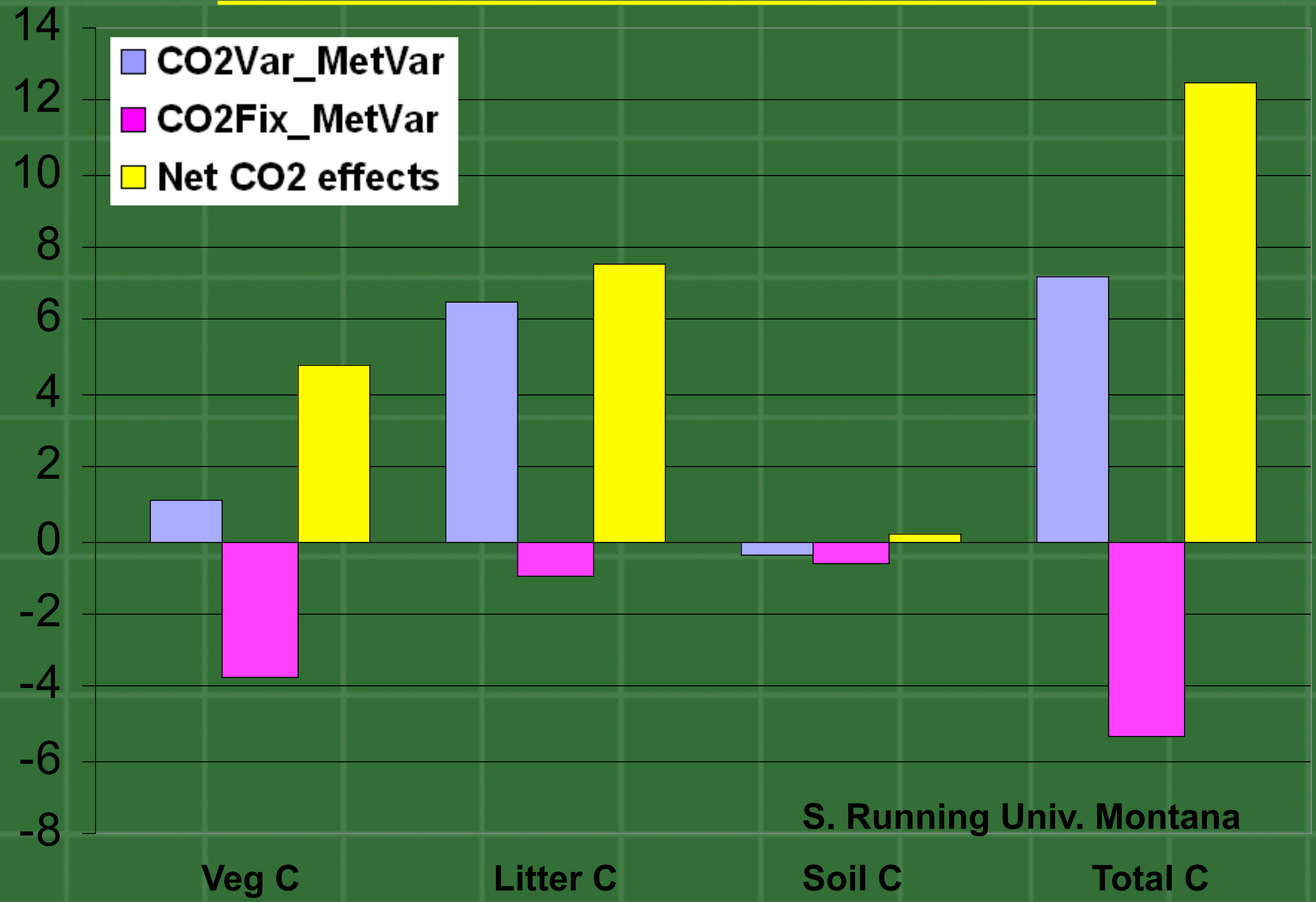
Spatial patterns of NPP changes

Large uncertainties

Need for multiple lines of evidence

Nemani et al., Science, 300

Carbon storage trends (Tg C/yr), 1961-2000



Challenges for the next 20 years

- Climate understanding requires consistent observations for tens of years
- We have looming interruptions in essential climate observations
- This will cripple our ability to respond to climate change adaptation and mitigation
- This will prevent enforcement of climate conventions, i.e. verification

Challenges for the next 20 years

Many key climate satellites have looming interruptions:

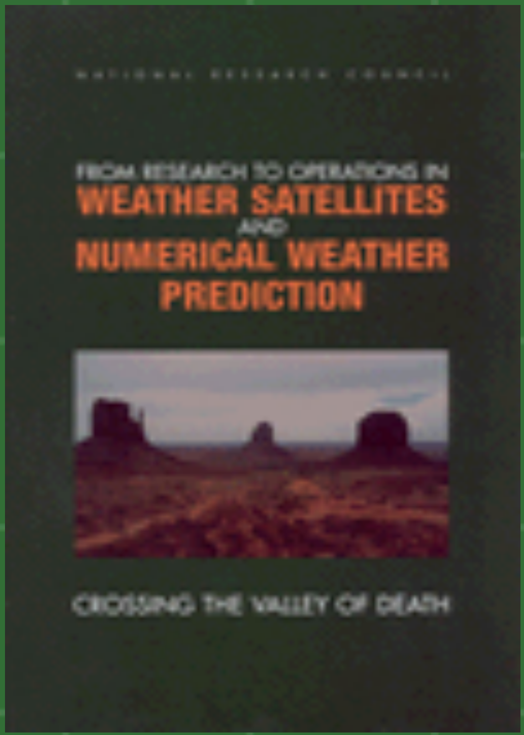
- Landsat's follow on mission (LDCM) will launch no earlier than 2013 and there is no follow on mission planned to that;
- MODIS depends upon continuation of VIIRS;
- GRACE's follow on scheduled for launch no earlier than 2020;
- Ocean color depends upon VIIRS;
- OCO-2 is critical to better understanding of carbon cycle and hence climate. Follow on no sooner than 2012.

The myth of “research to operations” climate observation transitions

We must strike the phrase “research to operations” from our vocabulary and use instead “research and operations”

Climate research, mitigation, and adaptation all require long term well-calibrated data to make informed decisions. These infrequently come from “operational” sources.

“Valley of death”.



FROM RESEARCH TO OPERATIONS IN WEATHER SATELLITES AND NUMERICAL WEATHER PREDICTION CROSSING THE VALLEY OF DEATH
Board on Atmospheric Sciences and Climate

The term “Crossing the Valley of Death” is sometimes used in industry to describe a fundamental challenge for research and development (R&D) programs. For technology investments, the transitions from development to implementation are frequently difficult, and, if done improperly, these transitions often result in “skeletons in Death Valley.”

Key land vegetation climate sensors

- Landsat
- AVHRR-MODIS-VIIRS
- DESDynl Decadal Survey mission laser and SAR
- SMAP Decadal Survey mission
- Orbiting Carbon Observatory

These are fundamental for climate understanding, climate change treaty verification, and carbon accounting

Land vegetation climate research sensors

- **ASCENDS – atmospheric laser sounder for CO_2 retrievals, day/night capability**
- **HyspIRI – hyperspectral Decadal Survey instrument**

These are research instruments that may improve our understanding of sources, sinks, and fluxes of carbon and contribute to carbon accounting

Thank Whomever a new day is here!

"Ladies and Gentlemen, it's time we gave some serious thought to the effects of global warming"